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IN THIS ISSUE

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News from the IPO

John Gould, Director, WOCE IPO

The start of 1994 saw major changes in the IPO, Nick Fofonoff returned to Woods Hole to embark on a well-deserved "retirement" after his 27 month spell as Director. We gave him and Mabel a good send off from IOSDL, we but we will miss them. During Nick's Directorship WOCE observations spun up and with the launch of ERS-1 and TOPEX/POSEIDON, a truly global perspective on the ocean was achieved. The satellite data have in several ways exceeded our expectations.

For those who don't know me, I have been involved with WOCE planning for a number of years, in fact way back to the mid 1980s when WOCE was first conceived. Latterly I have chaired the Core Project 3 WG and carried out UK WOCE cruises in the N. Atlantic and Southern Ocean. I am greatly honoured to have been selected as the most recent IPO Director but also somewhat daunted by the magnitude of the task of keeping track of the biggest and most complex oceanographic experiment ever undertaken.

Of the other IPO staff, Ilse Hamann, our Newsletter Editor is presently splitting her time between IOSDL and Hawaii. While this causes some difficulties in communication (no overlap of normal working hours between UK and mid-Pacific) it has enabled Ilse to concentrate on Pacific WOCE science. The most recent WOCE SSG was held in Tokyo, (the first time outside the USA or Europe) and we hope this has helped to strengthen activities in the Western Pacific. Penny Holliday has also changed her work mode dividing her time between IPO business and UK WOCE science. She has just completed the 1994 Resource Assessment before heading off for 6 weeks in the Southern Ocean. Sheelagh Collyer continues to be our office manager and corporate memory. She's the one who reminds me, the "New Boy", of all the things I need to do. We hope later in the year to get additional staff into the IPO funded by Germany and the USA.

One of my objectives is to keep WOCE in the public eye and hence to ensure that funding keeps flowing into WOCE even beyond 1997 so that we will be able to make the most of the WOCE data sets. As a first publicity venture the IPO will have a stand at Oceanology International '94 in Brighton UK to highlight the contribution that technology has made to WOCE. This newsletter will be available at OI'94. As the scientific results are published WOCE sessions have been scheduled for the Oceanography Society Meeting in Hawaii and WOCE will be a major focus at the South Atlantic meeting in Bremen.

Planning for the Indian Ocean is largely complete and the focus will then turn to the Atlantic where a revised strategy to study Gyre Dynamics is evolving. The Data Management Committee is addressing the complex issues of producing an integrated WOCE data set and the Numerical Experimentation Group, which has just published its Science Plan, is studying the problems of data assimilation.

WOCE has already produced some striking scientific results which are now appearing in the literature - much more will be published over the coming year. In order to be able to quantify what has been achieved the IPO has started the compilation of a WOCE bibliography. We will be seeking your help to make this as comprehensive as possible.

The articles in this Newsletter include encouraging evidence of the success of the TOPEX/POSEIDON mission - we hope that the satellite will continue to provide this high quality data to the end of its planned mission but have concerns that at present no follow-on with similar accuracy is planned.

Two articles on the comparison of WOCE sections with those taken tens of years earlier give insights into the spatial scales of temperature anomalies. By contrast, only at a very few sites do we have measurements of the temporal variability over decades.

GPS navigation is now being exploited to the benefit of many science projects (WOCE included) and the prospect of rms position errors below 10 m and heading accuracies of order 0.1° is likely to have a significant impact on the calculation of ADCP currents.

I hope in future issues we can continue to give prominence to WOCE successes as WOCE progress to maturity.

Colour images

Many of the most striking results from WOCE appear in the form of coloured images. Unfortunately, publishing costs stop us using colour in the Newsletter. We ask therefore if contributors will try to produce half-tone images so that they can be reproduced well in black and white.

Cruise Summary Reports (ROSCOP) Have you submitted yours?

The International Oceanographic Data and Information Exchange (IODE) system of the IOC has reporting procedures which are used to monitor the flow of data and to provide a referral service to data sources for other users.

Scientists in IOC member states are urged to submit a Cruise Summary Report (a Report of Observations/Samples Collected by Oceanographic Programmes) to the World Data Centres so that the IODE system is informed that data have been collected. Timely submission of the Cruise Summary Report is fundamental to the success of the IODE system.

All WOCE Chief Scientists are encouraged to submit a Cruise Summary Report through their national data centres or direct to a World Data Centre.

WHP Section A5 across 24°N aboard BIO Hesperides

Gregorio Parrilla, Instituto Español de Oceanografia, Madrid

On 20 July 1992, BIO Hesperides sailed from Las Palmas (Canary Is.) and arrived 27 days later at Miami, USA, fortunately a week earlier than expected and so avoiding Hurricane Andrew, which decimated Miami on our scheduled arrival date. During the cruise, WOCE Hydrographic Programme section A5 was carried out across the centre of the subtropical gyre in the North Atlantic. According to the WOCE Implementation Plan this line should have been located at 24°N. As two oceanographic sections had been made previously (in 1957 and 1981) at 24.5°N, the WOCE IPO and WHPPC agreed to move A5 to this latitude. We started at the 100 m-isobath at the coast of Africa and proceeded directly westward on 24.5°N. Near the Bahamas, the section was slightly deviated from 24.5°N in order to cross the continental slope perpendicular to the isobaths and to obtain a clear crossing of the Deep Western Boundary current. The cruise track and station positions are shown in Figure 1.

The section consists of 101 full-depth hydrographic stations, with a typical spacing of about 35 nm for the open ocean stations and around 20 nm for the stations near the boundaries and crossing the Mid Atlantic Ridge. In addition, a few stations were occupied during the passage leg between Cadiz and Las Palmas and 11 stations were made in a section across the Strait of Florida at 26°N. The objectives of the cruise were:

1. To carry out a water mass census and to document and study decadal changes in water mass characteristics;
2. To estimate meridional heat, freshwater, nutrient and CFC transports across the section and to compare them with those calculated in previous realizations; and
3. To contribute to the WOCE global data set.

Cruise participants belonged to the Instituto Español de Oceanografia, Consejo Superior de Investigaciones Cientificas, Universidad de Las Palmas, Woods Hole Oceanographic Institution, Lamont Doherty Geological Observatory and University of Miami.

Two NBIS/EG&G Mark IIIb CTD/O_2 underwater units were used. A General Oceanics rosette fitted with 24 Niskin bottles of 10 or 12 litre capacity was used with the CTD for collecting water samples. Water sampling included measurements of salinity, oxygen, nutrients (silicate, nitrate, nitrite and phosphate), chlorofluorocarbons (CFC-11 and 12), pH, alkalinity, CO_2, particulate matter, chlorophyll pigments, ^{14}C and aluminium. Data acquisition, processing and calibrations of CTD/O_2 data were done following the procedures given by Millard and Yang (1993).

To compare our new measurements with the earlier surveys of 1957 and 1981, the 2 dbar temperature, salinity, and oxygen data were smoothed with a binomial filter and then linearly interpolated (Mamayev *et al.*, 1991) to 35 standard levels for each station. Similar techniques were applied to the 1957 and 1981 measurements during the Hesperides cruise. Comparing our data with that obtained in 1957 and 1981, we find a general warming over the upper 3000 m during the entire 35 year period (Parrilla, Lavin, Bryden, Garcia and Millard, 1994). Figure 2 presents the temperature difference between 1992 and 1957, obtained by applying objective mapping techniques to each data set (Lavin, 1993). It is evident that a remarkably regular warming occurred between 700 and 3000 m depth. The isolines of temperature difference are nearly horizontal across most of the section. Both the North American and Canary Basins have warmed by about the same amount. Peak values are larger than 0.5°C at around 1000 m.

In water deeper than 3000 m significant cooling has been found in both basins. In Figure 3, zonally averaged temperature difference and its estimated error are shown as a function of depth. Positive values (warming) are found between 600 and 2750 m and between 200 and 400 m. Cooling occurred between 400 and 500 m and below 2750 m. The rate of warming between 1000 and 3000 m is

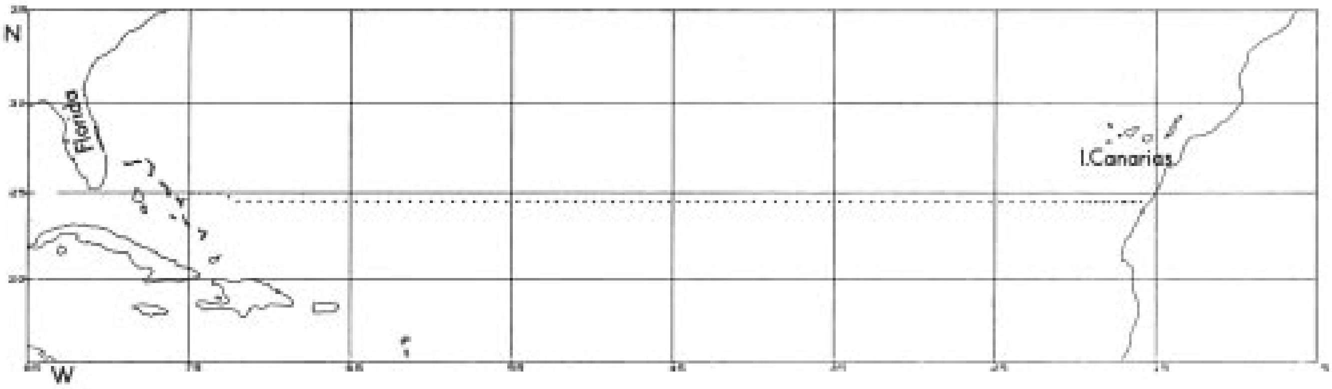

Figure 1. Station positions Hesperides Cruise 06 across 24.5°N (WHP section A5).

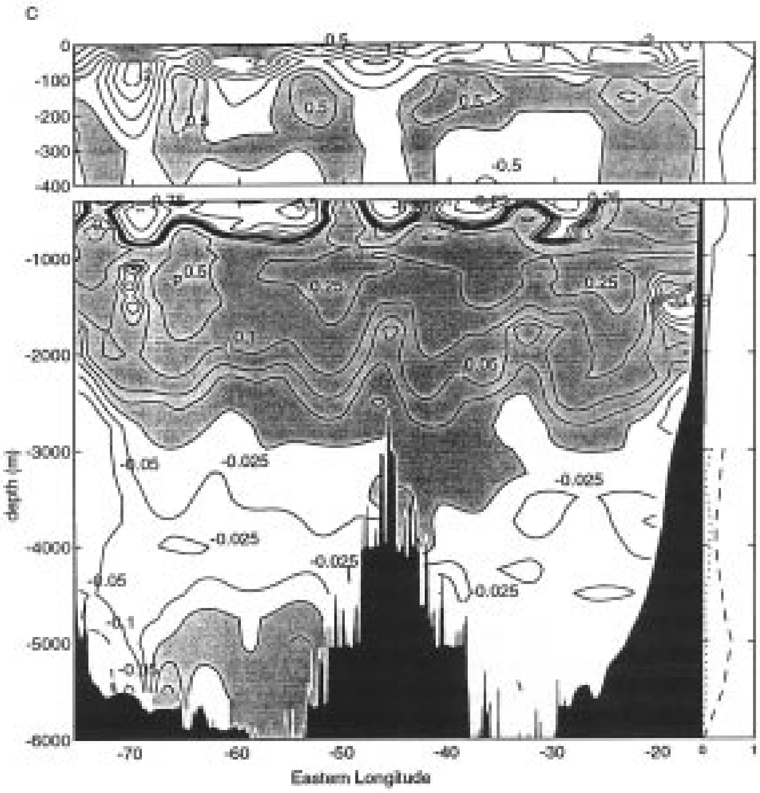

Figure 2. Temperature difference (°C) between 1992 and 1957. Shading indicates warming.

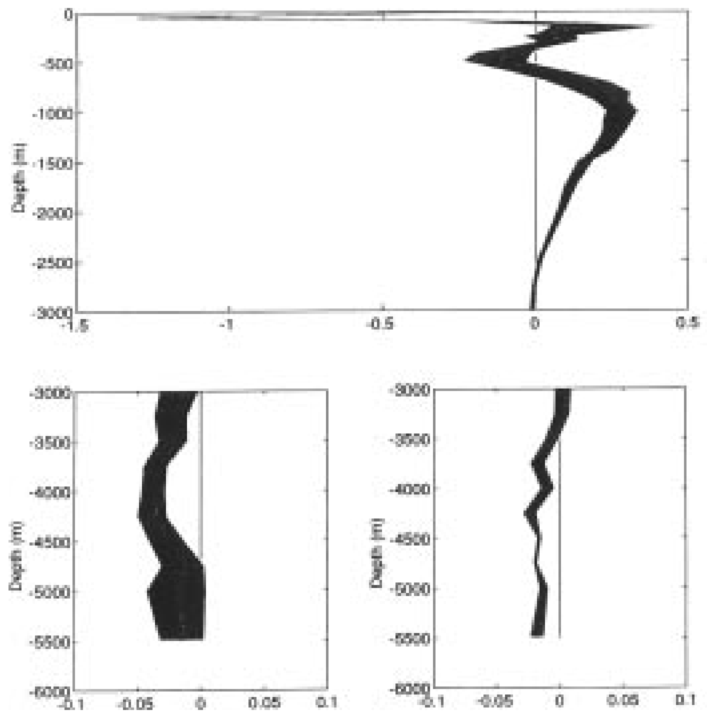

Figure 3. Zonally averaged temperature differences as a function of depth, plotted ±the error estimate (shading) for 1992-1957 period: from the surface to 3000 m for the entire North Atlantic Basin (upper plot) and deeper than that for the North American Basin (bottom left figure) and for the Canary Basin (bottom right figure). Data are in °C.

calculated to be 0.028 ±0.007°C/decade. The cooling below 3000 m has not been so regular, as strong cooling occurred in the Canary Basin for the 1981-1957 period and in the North American Basin for the 1992-1981 period. The changes in salinity are initially estimated to be about 0.003 psu/decade above 3000 m and 0.002 psu/decade below 3000 m in the North American Basin and 0.001 psu/decade in the Canary Basin. We also note that there is a general freshening, as well as a cooling, in the western boundary region near the Bahamas below 2000 m. The eastern boundary appears to have a similar trend but to a lesser extent.

Such long term changes in ocean temperature have important implications for understanding the nature of climate change. In combination with Read and Gould's (1992) observations of cooling in the North Atlantic subpolar gyre over a comparable period, this warming in the subtropical gyre that we have observed at 24.5°N suggests that the pattern of global change may be quite complicated. We are continuing to analyse the Hesperides 24.5°N measurements and to compare them with the previous surveys in 1957 and 1992. Of primary interest is to determine whether or not there have been changes in the temperature-salinity-oxygen characteristics of the various water masses in the subtropical North Atlantic Ocean.

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Western North Atlantic cools at intermediate depths

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In July 1993 the German RV Gauss worked the proposed WOCE hydrographic section A2 along 48°N in a repeat mode from Halifax to Hamburg (figure 1). In the western Atlantic the section leaves the Newfoundland shelf perpendicular to it and runs parallel to the Canadian mooring array ACM6. At station 23 it joins the old 1957 RRS Discovery section towards the Mid-Atlantic Ridge. From here it continues towards the European shelf closely following the 1982 Hudson section. On the outward leg Gauss completed a high-density deep XBT/XCTD-section AX3 and deployed five current meter rigs off the North-European Shelf and on the western side of the Mid-Atlantic Ridge (MAR) at *ca.* 48°.

The hydrographic section reveals considerable changes in the water mass characteristics at intermediate depths since the early 1980s. The Labrador Sea Water (LSW) with its clear oxygen and salinity signal now was found at depths of more than 2000 m in the Western basin, the core temperatures down to ca. 3.2°C. Compared to the last section of comparable quality, worked by the Canadian CCS Hudson on cruise 82-002 in April 1982, the LSW properties in the western basin are markedly different (figure 2). Most conspicuous is the depth of the LSW east of Newfoundland, that increased by 700 m from *ca.* 1400 m in 1982 to more than 2100 m in July 1993. The temperatures are cooler by 0.4 to 0.5°C, and salinities are only slightly fresher by less than 0.01. On first estimates, the amount of LSW has more than doubled from 1982 to 1993 at 48°N.

Remarkable is the decrease in changes when passing over the MAR into the Eastern Basin. Immediately east of the ridge, the LSW is found almost at the same depths of *ca*. 1800 m as in 1982, the temperatures are some 0.1°C cooler and salinities have decreased by *ca*. 0.01 - 0.02.

Similar changes were reported for the 24.5°N section, worked by the Spanish RV Hesperides in 1992 (Lavin, 1993) with cooling in the intermediate layers of the western basin by 0.1°C since 1982, and warming of ca. 0.05°C in the Eastern Basin. Recent work on 36°N in 1993 by the Russian RV Prof Multanovskiy (Tereshenkov, pers. comm.) confirms these changes, with temperature changes slightly less in the west, and east of the MAR constant or slightly higher temperatures. Roemmich and Wunsch (1984) observed for the period 1957 to 1981 on 24.5°N the opposite: a slight warming of about 0.2 in the western basin, and a cooling of 0.05 in the intermediate depths between 1500 and 3000 m of the Eastern Basin. Salinity changes for these periods are reverse to the temperature changes, slight freshening coincides with cooling, and slightly higher salinities are observed with warming.

Overall these changes suggest long-term variations on decadal time-scales of the intermediate layers of the North Atlantic, with reversed tendencies between 1957 to 1981/82 and 1981/82 to 1992/93 in both the Western North-American Basin and the Eastern European Basin. Looking for changes at the source of LSW, most recently Lazier and Gershey (1991) noted the continued decrease in LSW temperatures along WOCE section A1W since the late 1980s. Cooling has increased even further and the depth of convection deepened considerably since and to 1993 (Lazier, pers. comm.). These processes drive changes of the production rates of LSW and its property characteristics.

Read and Gould (1992) observed the first evidence of this large-scale and drastic change of the LSW properties and distribution in the Northeastern Atlantic, with cooling of 0.15°C from 1981 to 1991. They suggest a direct route for the LSW to arrive from its area of origin in the Northeastern Atlantic Basin and the Rockall Trough. Evidence from

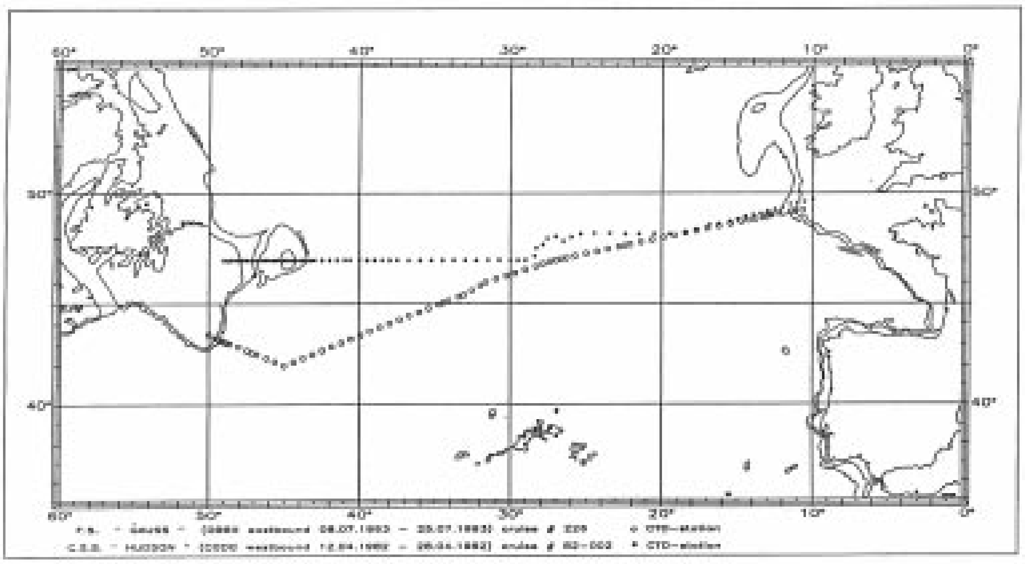

Figure 1. Station map of the Gauss cruise along A2, July 1993, and the 1982 Hudson stations.

36°N and 24.5°N suggest an alternative or supplemental more southern route for the LSW around the North Atlantic. As the temperature changes observed in the Eastern Atlantic for these periods run counter to those of the Western Atlantic, the question still remains: are these remnants of the previous warmer LSW production class circulating now through the eastern half of the North Atlantic?

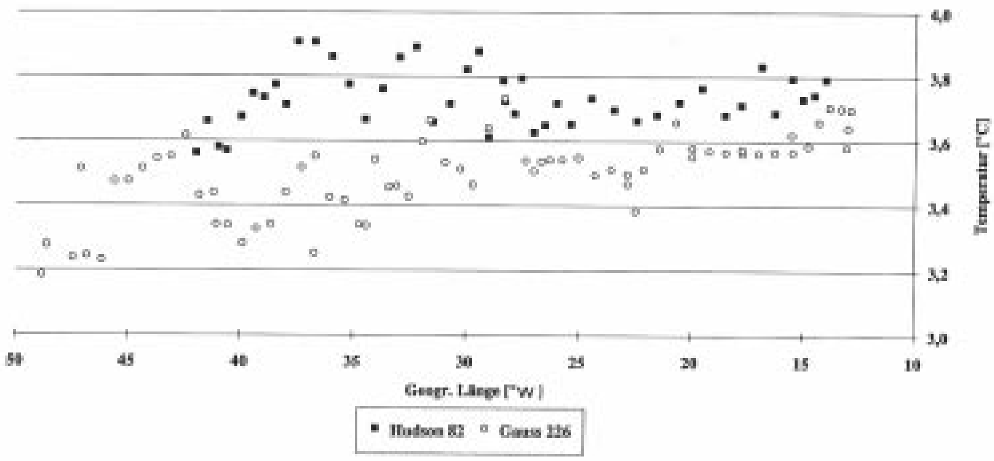

Figure 2. The Labrador Sea Water Temperature Minimum along the 48°N section. Hudson (■) in 1982, Gauss on A2 in July 1993 (o).

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Scientific Background of JMA Oceanographic Surveys along PR2

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Introduction

The Japan Meteorological Agency (JMA) has carried out oceanographic surveys along the 137°E meridian from the southern coast of Japan to the offing of New Guinea since 1967 in winter and since 1972 both in winter and summer.

This project was initiated in 1967 as a part of the Cooperative Study of the Kuroshio (CSK) sponsored by the Intergovernmental Oceanographic Commission, UNESCO. [Inspired by R. Montgomery's proposal "Oceanographic Shuttle" J. Masuzawa became responsible for the planning of this project, Masuzawa and Nagasaka, 1975.] Since 1967 the survey of the 137°E meridian has been routinely conducted with the purpose of

(1) detecting long term variation of oceanic conditions in the western North Pacific connected with climate change and
(2) monitoring background marine pollution.

The observation line was chosen to obtain data undisturbed by islands and submarine mountains. It spans across the Shikoku, the West Mariana and the West Caroline Basins. Surveys are carried out by RV Ryofu Maru of JMA from north to south in the second half of January and from south to north in July every year. Typical distance between neighbouring hydrographic stations is 60 nautical miles, (30 nautical miles south of 8°N). Deep hydrographic observations to 4000 m or 5000 m depth are made at every 5 degrees from 30°N to the equator. CTD observations were started in the summer of 1988 replacing reversing thermometers and Nansen bottles. Observational elements are currents, water temperature, salinity, dissolved oxygen, nutrients, pollutants, phytopigments, zoo- and phyto-planktons. Greenhouse effect gases have been included in the list of observational parameters since 1989 in relation to the problem of global warming.

Results

General Oceanographic Features

The line is located in the western periphery of the North Pacific subtropical gyre, and crosses the Kuroshio south of Japan, then the Kuroshio Countercurrent, the Subtropical Countercurrent, the North Equatorial Current and the North Equatorial Countercurrent. A warm water pool with temperatures higher than 28°C exists in the surface layer in the western Pacific equatorial region. Cooler, but still relatively warm water occupies the mid-depth range south of Japan, and it forms the western boundary region of the subtropical gyre.

The core of the North Pacific Tropical Saline Water (NPTSW) is in the surface layer in the central part of the subtropical gyre. It extends westward and eastward in the subsurface layers with potential densities between 24.0 and 25.0 and can be seen on PR2 between 13°N and 18.5°N. North Pacific Intermediate Water (NPIW) is found slightly deeper and originates in the subarctic region of the North Pacific and spreads along the subtropical gyre forming a salinity minimum layer centred around potential density 26.7. Fresher surface water is found in a zonal band between 10°N and 15°N. Another saline surface water mass carrying the signature of South Pacific Tropical Saline Water (SPTSW) spreads westward along the equator as far as 160°E and traces can be found between 1°S and 4.5°N at 137°E.

Mean and Variability of Winter Conditions

Figure 1 indicates the winter mean water temperature along the line averaged over the 21 winter cruises from 1967 to 1987 (MRI, 1992). The isotherms within the thermocline abruptly deepen as they intersect the Kuroshio between latitudes 33°N and 31°N and are deepest around 31°N marking the southern boundary of the Kuroshio. The isotherms gradually shoal southward and are shallowest around 7°N or 8°N where the thermocline is sharpest. The Kuroshio Countercurrent and the North Equatorial Current flow westward between 31°N and 7°N. The eastward flowing Subtropical Countercurrent is not apparent from the inclination of the isotherms. The North Equatorial Countercurrent flows eastward south of the isotherm ridge around 7°N. Warm water with temperatures higher than 28° occupies the surface layer shallower than 50 m south of 8.5°N.

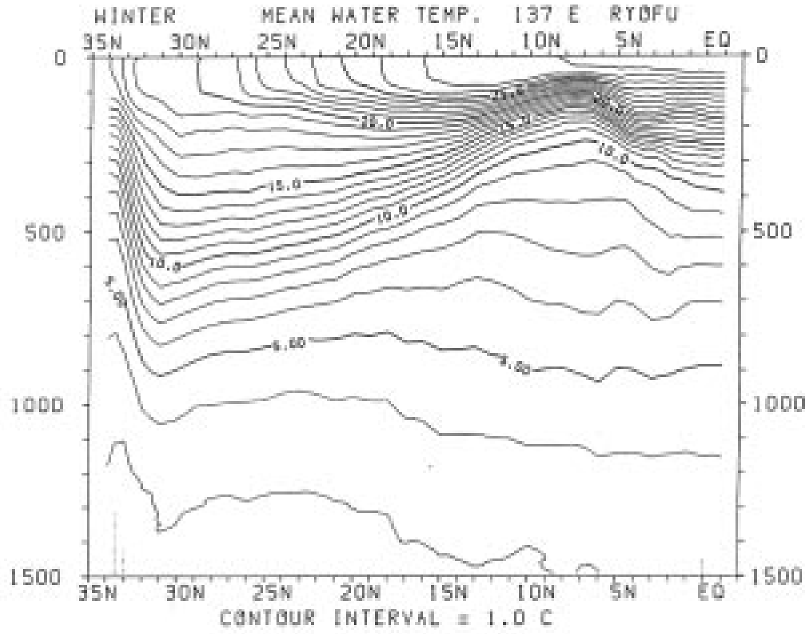

Figure 1. The winter mean water temperature in the 137°E section (PR2) averaged over 21 winter cruises from 1967 to 1987.

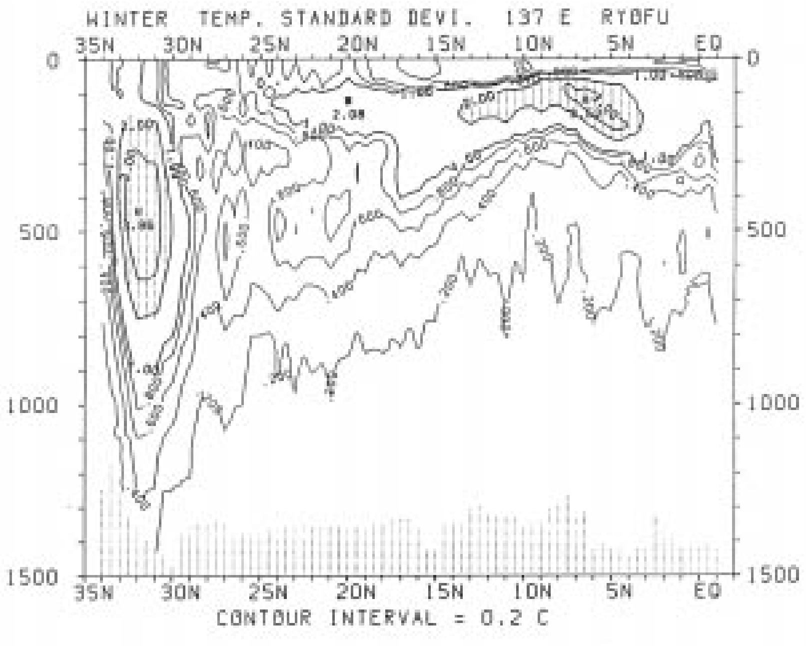

Figure 2. The standard deviation of water temperature observed in winter from 1967 to 1987.

Figure 2 shows the standard deviation of water temperature along the 137°E section, derived from all winter cruises between 1967 and 1987 (MRI, 1992). There are two major regions with large variation. One is found between 30°N and 33°N between 200 m and 750 m depth, and is associated with the path variation of the Kuroshio. Another is the region from 3°N to 14°N between 100 m and 250 m depth, where vertical movement of the thermocline is induced by El Niño and La Niña events. Variability of water temperature is larger in the North Equatorial Countercurrent than in the North Equatorial Current. As seen from the distribution of isopleths of 1°C standard deviation, variability is relatively large along the seasonal and main thermoclines.

Figure 3 shows the winter mean salinity for the same period as Figure 1 (MRI, 1992). The NPTSW centred around 35.0 psu appears from 13°N to 19°N between 100 m and 200 m depth, and the saline water from the South Pacific extends northward as far as 4.5°N between 100 m and 300 m depth. NPIW, centred around 34.3 psu, exists north of 15°N between 500 m and 1000 m depth forming a salinity minimum layer. Salinity is fairly uniform below those water masses. Water fresher than 34.3 psu spreads in the surface layer shallower than 50 m depth between 6°N and 12°N.

Interannual Variation

From the time series of water temperature anomalies in the upper 500 m layer (not shown here) remarkable negative and positive anomalies appear south of 15°N in El Niño and La Niña events, respectively. As an exception, negative anomalies appeared in the tropics of the western Pacific in 1980 and 1981, without an El Niño event taking place. Another conspicuous negative anomaly extended northward from the equator as far as 25°N in winter 1973. Other remarkable negative anomalies occurring north of 30°N were associated with large meandering of the Kuroshio from 1976 to 1979.

Summary

We can summarize the scientific background of oceanographic surveys along 137°E as follows:

1. The observation line along the 137°E meridian is suitable to monitor accumulation and discharge of warm water accompanied by La Niña and El Niño events.
2. Interannual variation of the subtropical gyre in the North Pacific is apparent as fluctuations of the amount of NPTSW (PR2 lies in the western portion of the subtropical gyre).
3. Interannual variation of the subtropical gyre is also indicated in the change of the whole oceanic structure along the line as exemplified in winter 1973.
4. The interannual variation of the subtropical gyre is suggested to be related to the change in the wind field. Quantitative analyses are required to clarify dynamical relationship between them.
5. Interannual variation of the NPIW is shown, but the cause for the variability remains to be solved.

The area of the NPTSW in the 137°E section had been diminishing since 1967 and almost disappeared in winter 1973 (Figure 4). After that, weak re-appearance continued until 1977 reaching a sharp peak in winter 1978, and the presence of NPTSW diminished gradually after 1979. Thus the appearance of the NPTSW at 137°E shows interannual variation with a clear tendency to be weakened during El Niño periods.

The extension of saline water from the South Pacific was also weak in winter 1973 and in summer 1983, but its interannual variation is less clear than that of the NPTSW.

The size of the area occupied by the freshest water mass (NPIW, enclosed by the 34.16 psu isohaline), varies with a period of about four and half years, with the northern part of the salinity minimum region showing greater variation than the southern part of the core. The thickness of the NPIW, defined by the distance between the two 34.2 psu isohalines was narrowing during the large meandering of the Kuroshio from 1976 to 1979.

Oceanic Conditions in Winter 1973

Very abnormal oceanic conditions prevailed on the 137°E section in winter 1973 when the El Niño event was in its final stage. At this time the negative temperature anomaly reached its northernmost extension and NPTSW disappeared. The sea condition in winter 1973 is described in detail.

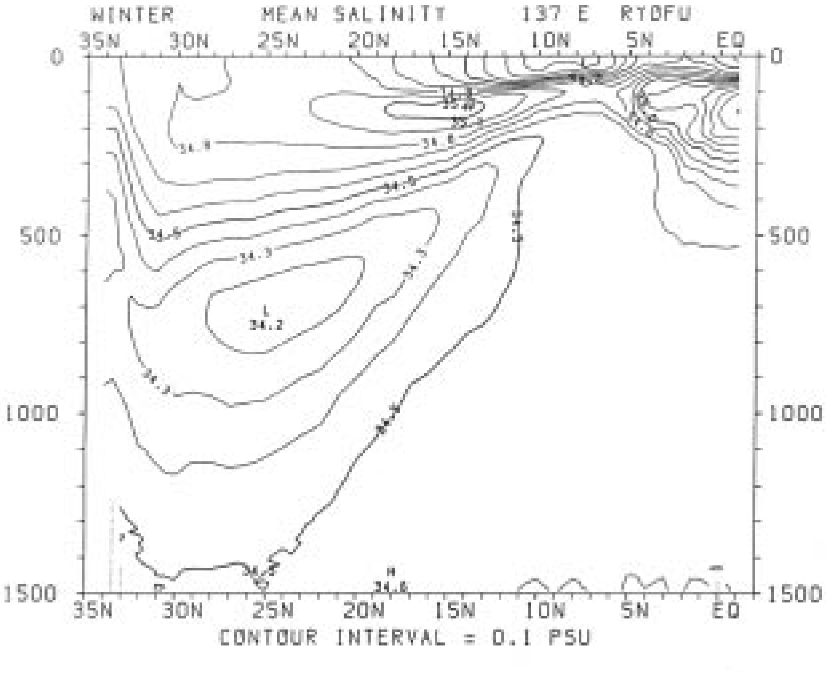

Figure 3. The winter mean salinity in the 137°E section (PR2) averaged 21 winter cruises from 1967 to 1987.

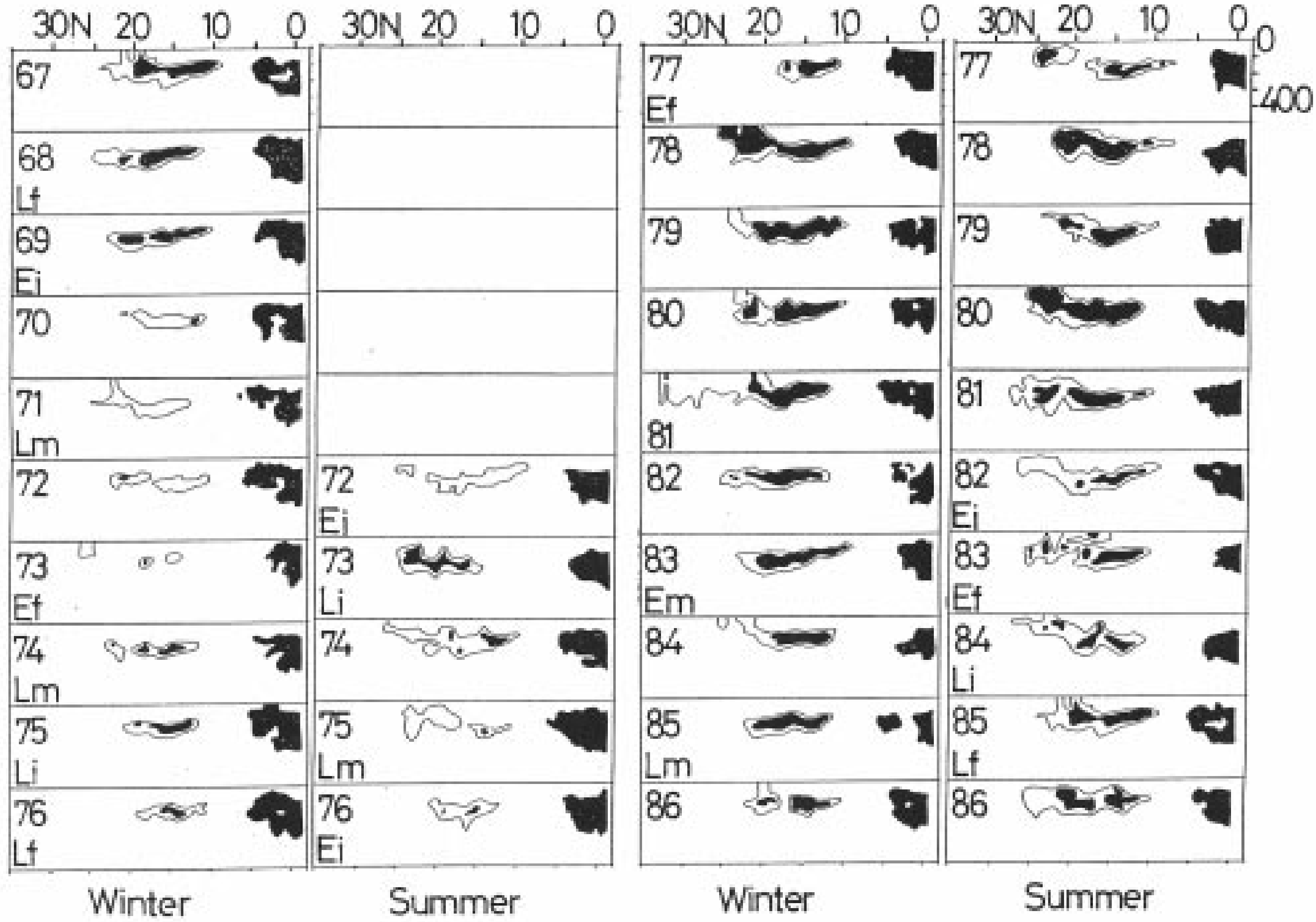

Figure 4. The time series of salinity section in the upper 500 m layer along the 137°E meridian focusing on the North Pacific Tropical Saline Water (NPTSW) and saline water from the South Pacific which are defined with having salinity higher than 35.0 psu and painted black. "E" and "L" stand for El Niño events and La Niña events, respectively. Subscripts "i", "m", and "f" represent initial, mature, and final stages of each event, respectively.

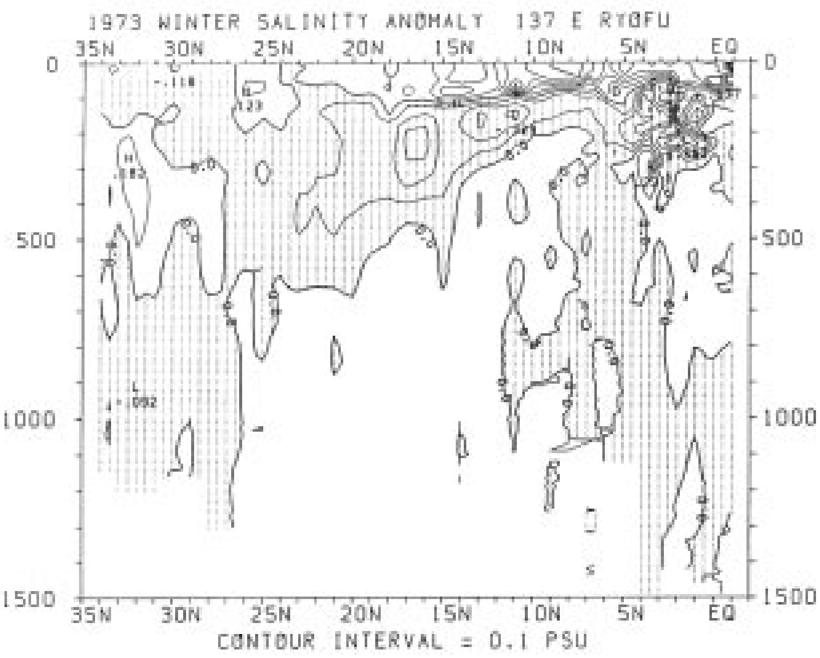

Figure 5. The salinity anomaly in the 137°E section in winter 1973.

The negative anomaly of water temperature occupied almost the whole region south of 30°N. Figure 5 shows the salinity anomaly in winter 1973 (MRI, 1992). If we compare this figure with Figure 3, we can see that the negative anomaly occurs above the centre of the salinity minimum layer and the positive anomaly below the centre. Those anomalies of water temperature and salinity suggest that the whole oceanic structure shoaled south of 30°N in winter 1973. The NPTSW is formed by excess of evaporation over precipitation at the sea surface and surface water is subducted into the subsurface layer by convergence of the Ekman layer in the central part of the North Pacific subtropical gyre. The subtropical gyre is driven by westerly wind stress in mid-latitudes and north-easterly trade winds in low latitudes. To investigate the reasons for the anomalous temperature and salinity conditions we studied wind fields.

In the monthly mean wind stress curl field averaged over 23 years from 1961 to 1983 negative wind stress curl occupies the region of the subtropical gyre in January and February. The negative value is strongest south-east of Japan, which means strong convergence of the Ekman transport there. One year before the anomalous oceanic conditions were observed in winter 1973, the negative value of wind stress curl was very weak in the region of the subtropical gyre (*i.e.* in January and February 1972). It is suggested that the anomalous wind fields in the 1972 winter have induced the peculiar sea condition in winter 1973.

This is at odds with the findings of Qiu and Joyce (1992), who point out that interannual fluctuations of geostrophic transport of the North Equatorial Current and the North Equatorial Countercurrent in the 137°E section have high simultaneous correlations to the Sverdrup transport fluctuations estimated from the basinwide wind-stress curl field. The author showed here that a causal relationship could exist between the one year precedence of wind-stress curl field change and the change of oceanic conditions in the 137°E section in winter 1973.

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Decadal Changes of the Thermal Structure in the North Pacific

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Introduction

Recently strong interdecadal signals were found in the time series of sea level pressure, 500 hPa height and sea surface temperature (SST) from the mid-latitude region of the North Pacific. The equatorial atmosphere/ocean coupled system tends to be highly correlated with these decadal variations through the Pacific-North American teleconnection in the atmosphere (Nitta and Yamada, 1989). On the interannual time scale, the most pronounced SST anomaly pattern in the North Pacific has an elliptical shape centred at 40°N and stretching zonally (Weare *et al.*, 1976, Iwasaka *et al.*, 1987). Tanimoto *et al.* (1993) showed that this spatial pattern is also dominant on the decadal time scale. They pointed out that a step-like SST change occurred in the mid-1970’s and the SST in the mid-latitude region became cool after that.

It is postulated that corresponding changes occurred in the subsurface thermal field and current system. The ocean may play an important role in generating a low frequency response of the atmosphere/ocean coupled system. For the western part of subtropical gyre, several efforts have been made to understand the long term variations. Lie and Endoh (1991) showed that the variation related to ENSO is significant in the western North Pacific. By using the long term hydrographic

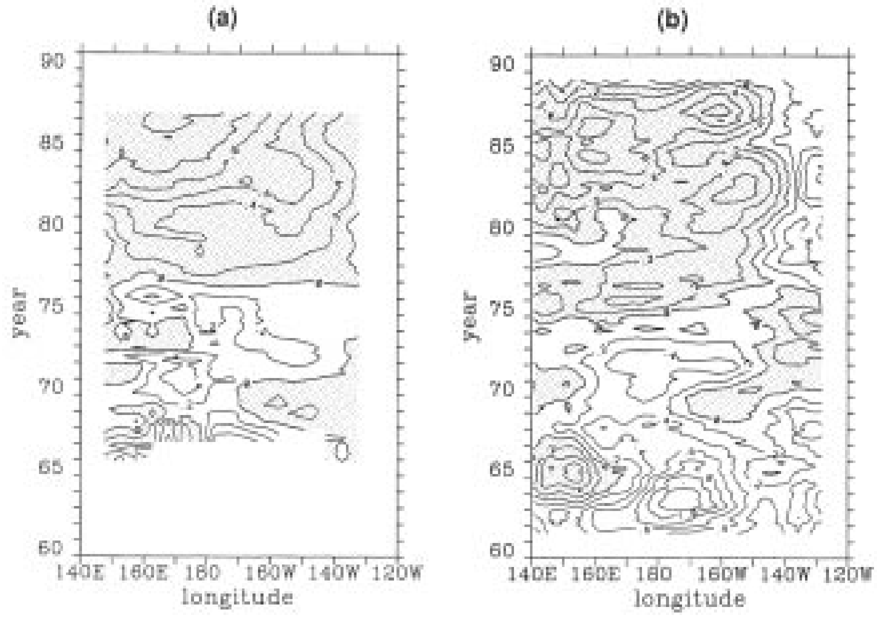

Figure 1. (a) Time longitude matrix of 0-400 m vertically averaged temperature anomalies (T0-400) along the 35°N - 45°N latitude band. Time series at each grid point are a 3-year running average. Contour interval is 0.2 °C and negative values are shaded. (b) Same as 1(a) except for SST. SST data set was provided by JMA.

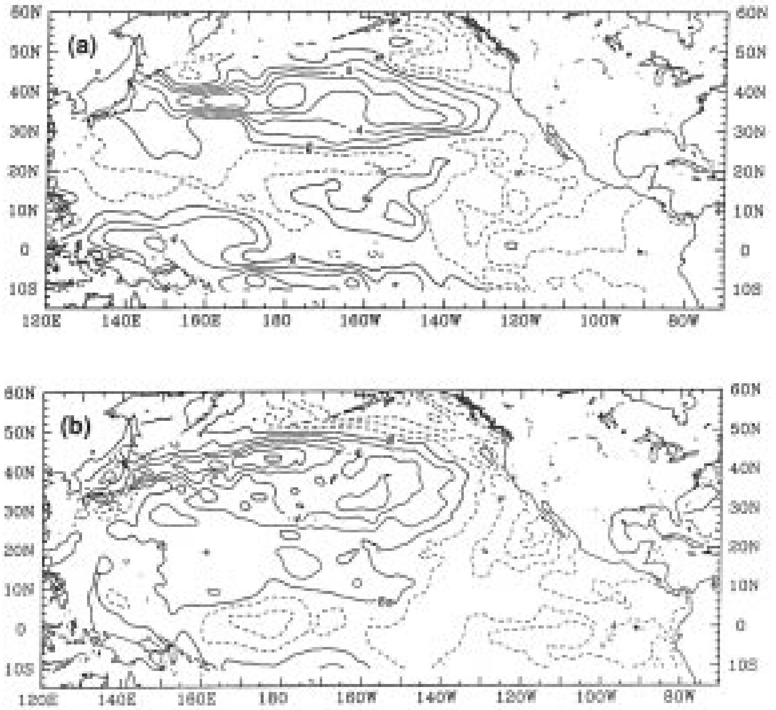

Figure 2. (a) Difference field for the T0-400 between the period 1966-75 and the period 1976-85. Contour interval is 0.2°C and positive contour is dashed. (b) Same as 2(a) except for SST.

data along 137°E obtained by JMA during 1967-1988, Qiu and Joyce (1992) found interdecadal variations in the transport of the Kuroshio and the North Equatorial Current. Bingham *et al*. (1992) showed that the transport of the subtropical gyre was stronger during the period 1978-82 than in the period between 1938 and 1942.

In this study, we investigate the interdecadal variations of subsurface thermal structure related to the change in the North Pacific atmosphere/ocean system observed in the mid-70's.

Data

The historical temperature-depth profiles used in this study were constructed by merging NODC and NRIFSF (National Research Institute of Far Seas Fisheries) data sets. It also contains TRANSPAC XBT data. The data set contains about 1.8 million profiles for the Pacific Ocean between the 50°S and 60°N latitude circles and the 100°E and 70°W meridians.

Each original temperature-depth profile was interpolated to standard depths. We calculated long term climatic monthly mean and standard deviation for each 5 x 5 latitude/longitude box. Data differing from these means by more than 3 standard deviations were rejected. First, monthly maps of were calculated for each month during 1964-88. Then, these maps were converted to successive seasonal maps (January-March, April-June, July-September, October-December) for the same period. Finally, each seasonal map was zonally averaged with a running mean spanning 3 boxes (15 degrees of longitude), and 100 individual seasonal thermal field data sets were obtained.

Results

Based on the seasonal, zonally averaged 5 x 5 degree box temperature data set, anomalies (deviations from seasonal climatological mean) were calculated for the period 1971-80. Then, we applied a 13 season (37 months) running mean to the data set of SST anomalies. Figure 1(a) shows the time longitude matrix of anomalies of temperature averaged over the upper 400 metres along the 35-45°N latitude band. For comparison, we constructed a similar figure for monthly mean SST (provided by JMA, 2 x 2 degree boxes) in Figure 1(b). Both SST and T0-400 show quite similar patterns, and cold anomalies dominated after the mid-1970's. During this period cold anomalies in the subsurface temperature tended to follow SST with some time delay. For the eastern part, two cold SST maxima during 1982-83 and 1986-87 are shown. These anomalies are possibly formed under the influence of atmospheric conditions related to the 82/83 and 86/87 ENSO events. These longitudinal positions of ENSO related signals are consistent with the EOF pattern for the ENSO time scale (Tanimoto *et al.*, 1993).

Tanimoto *et al.* (1993) also showed that SST flipped from a predominantly positive anomaly state to a state of mostly negative anomalies in the mid-1970's on the decadal time scale. In order to inspect this change, we compared two decadal climatologies of the annual mean thermal field for the periods 1966-75 and 1976-85 in the North Pacific. Figures 2(a) and 2(b) show differences between the two periods, for T0-400 and SST respectively. In both figures cooling in mid-latitudes is pronounced, and cooling in SST after the mid-70's had a coherent spatial structure in the subsurface thermal field. In mid-latitudes two intense cooling regions east and west of 170°W can be seen. The centre of the western one is located around the dateline and the eastern one is centred around 160°W. These centres are aligned approximately with the subtropical-subarctic boundary across which a strong meridional temperature gradient exists; after the mid-70's a southward shift of the boundary occurred.

In the equatorial region, cold anomalies also appeared in the upper 400 m in the western Pacific, accompanied by warm SST anomalies along the equator around the date line and off South America. They reflect the upward shift of the thermocline in the western part, and eastward movement of warm water. This suggests the equatorial atmosphere/ocean coupled system tended to be in an El Niño-like state after the mid-1970's.

To investigate the changes of the subtropical gyre structure, averaged vertical (meridional) temperature sections for the two periods, and a section showing their differences, were constructed. Figures 3(a) and 3(b) are the mean temperature sections along the longitude band 170-180°E for the periods 1966-75 and 1976-85, respectively. The difference between them (Figure 3(c)) shows that cooling in the mid-latitude region reached from the surface down to 400 m, but cooling in the equatorial region is confined to above the thermocline at 100-200 m depth. In the subtropical region, weakly positive anomalies appeared from the surface to 400 m. This distribution reveals a deepening of the subtropical gyre and intensification of the subtropical-subarctic front. The anomalies in the equatorial region can be ascribed to the upward shift of main thermocline. This implies that the southern part of the subtropical gyre was also intensified after mid-1970's.

To follow the change of thermal structure in more detail, time-series of year-to-year anomaly maps (not shown) were constructed by averaging 4 successive seasonal maps of a year. They suggest that mid-latitude anomalies propagate southward. To check this phenomenon, a one-point correlation analysis was applied to the 5-year running mean data set.

A time-series of annual mean temperature anomaly of 10 m depth at 172.5°W, 32.5°N was selected as a reference point. Figure 4 shows the correlation map for 400 m temperature at 2 years lag. Higher correlation can be found in the area to the east of reference point in mid latitudes. A southward intrusion of positive correlations to 15°N around 130°W can be seen. This intrusion pattern is similar to the distribution of the salinity minimum at subsurface depths (Yuan and Talley, 1991). We therefore speculate that ventilation along the northern boundary of the subtropical gyre may be a possible mechanism for the southward propagation of the anomalies.

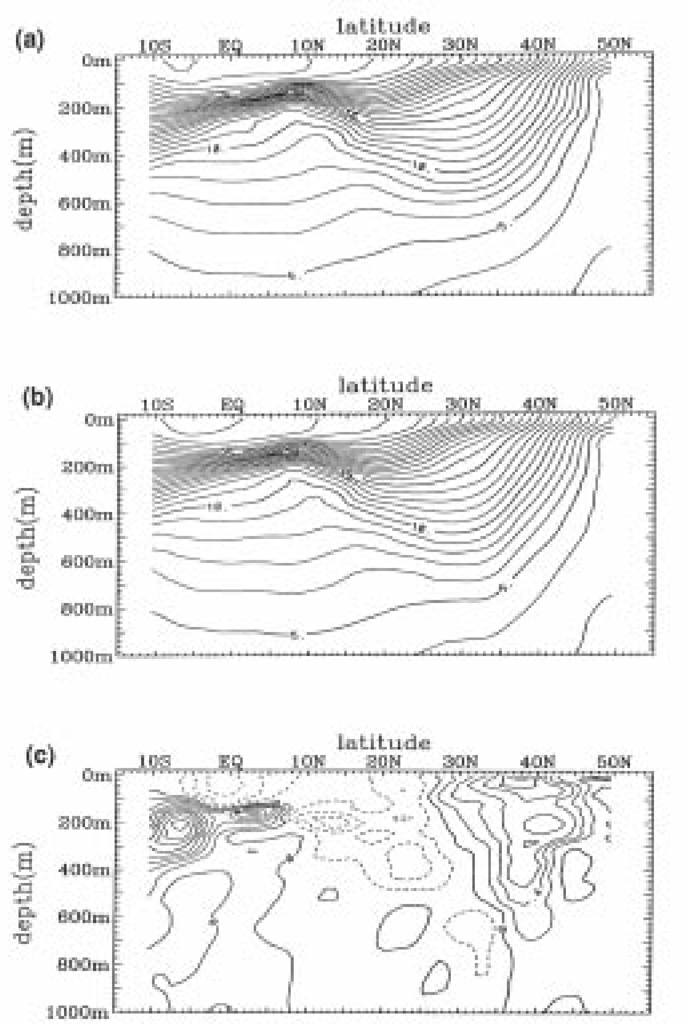

Figure 3. (a) Meridional vertical section of temperature along the 170°E-180° longitude band for the period 1966-75. Contour interval is 1.0°C. (b) Same as 3(c) except for the period 1976-85. (c) Meridional vertical section of temperature difference along 170°E-180° longitude band between 1966-75 and 1976-85. Negative value means colder in the period 1976-85. Contour interval is 0.2°C and positive contours are dashed.

Discussion and Conclusion

Systematic change in the subsurface thermal field implies intensification of the subtropical gyre after the mid-1970's. Recently, Endoh *et al*. (1993) performed a numerical experiment for the interannual variations in the Pacific using real SST and wind stress data. They show similar results for the interdecadal variations, and pointed out that the stronger Ekman pumping deepened the subtropical gyre after the mid-1970's. Qiu and Joyce (1992) also showed that decadal trends in the transports of the Kuroshio and the North Equatorial Current at 137°E are correlated to the subtropical wind stress field.

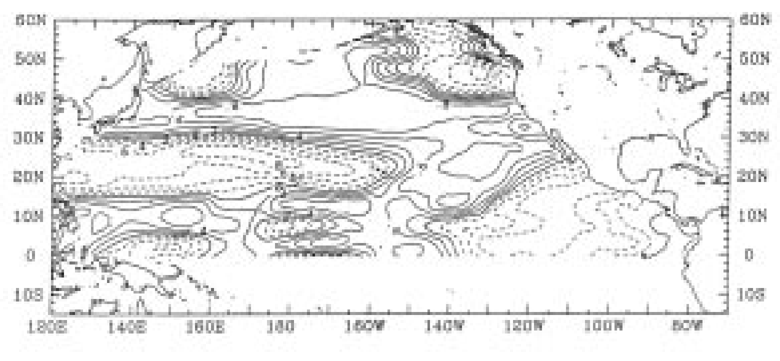

Figure 4. One point correlation map for 400 m temperature at 2 years lag with the reference time series of 10 m temperature at 172.5°W, 32.5°N. Contour interval is 0.2 and positive contours are dashed.

We demonstrated strong interdecadal variations in the subsurface thermal structure in the North Pacific and their potential to change the strength and thermal structure of the subtropical gyre by a ventilation mechanism on decadal time scales. It is therefore important to collect long term subsurface thermal data in the mid-latitude North Pacific. TRANSPAC type field monitoring is necessary for climate forecasting on decadal time scales.

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SR1 Repeat Hydrography/ADCP, Drake Passage, November 1993

Brian King and Steven Alderson, IOS Deacon Laboratory, Wormley, UK

A CTD/ADCP section was run along WOCE repeat hydrography line SR1 in November 1993.

RRS James Clark Ross sailed from Stanley, Falkland Islands, on 20 November 1993, the main purpose of the cruise being logistics and base relief for British Antarctic Survey bases west of the Antarctic peninsula. Additionally, BAS made available two berths and three days of station time for CTD work in Drake Passage. The section was along the revised position of SR1 (sometimes known as SR1b), which coincides with an ERS-1 ground track. This section had been occupied to 400 metres with ADCP and SeaSoar from RRS Discovery in November 1992 (WOCE Newsletter 14, page 27) and the northern part with CTDs from the Polarstern in September 1992 (R. Peterson, pers. comm.). It is anticipated that the UK will undertake further repeat hydrography on this section during the 1994/5 season. The shipboard ADCP programme was supplemented with an Ashtech GPS3DF to provide high-quality ship heading measurements (described by King and Cooper, 1993) and by Differential GPS position fixing relative to a static station in Stanley.

The principal objective of the IOSDL programme was to produce a repeat hydrography dataset suitable for calculating the volume flux of the ACC at the longitude of the section.

The bulk of the CTD data were collected during the first 7 days of the cruise, and consisted of 30 full-depth stations between Burdwood Bank and Elephant Island,

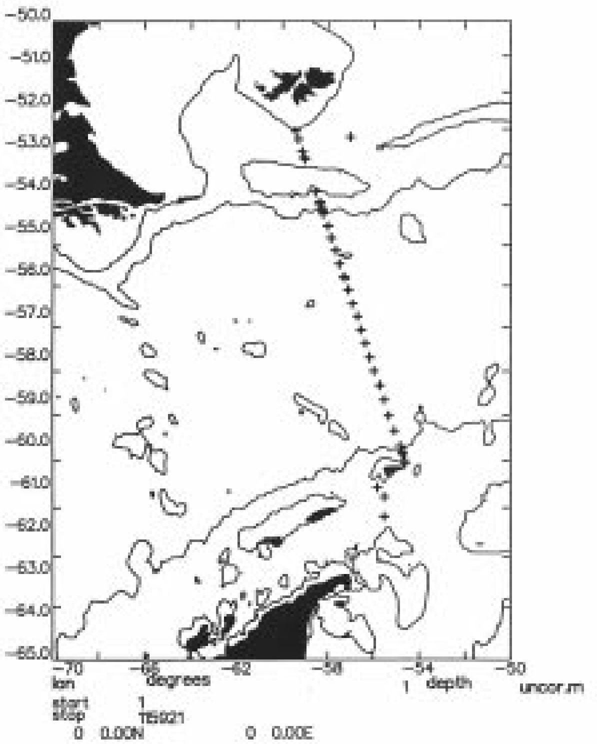

Figure 1. Positions of CTD stations occupied on RRS James Clark Ross, November/December 1993. The 200 and 3000 metre isobaths are shown.

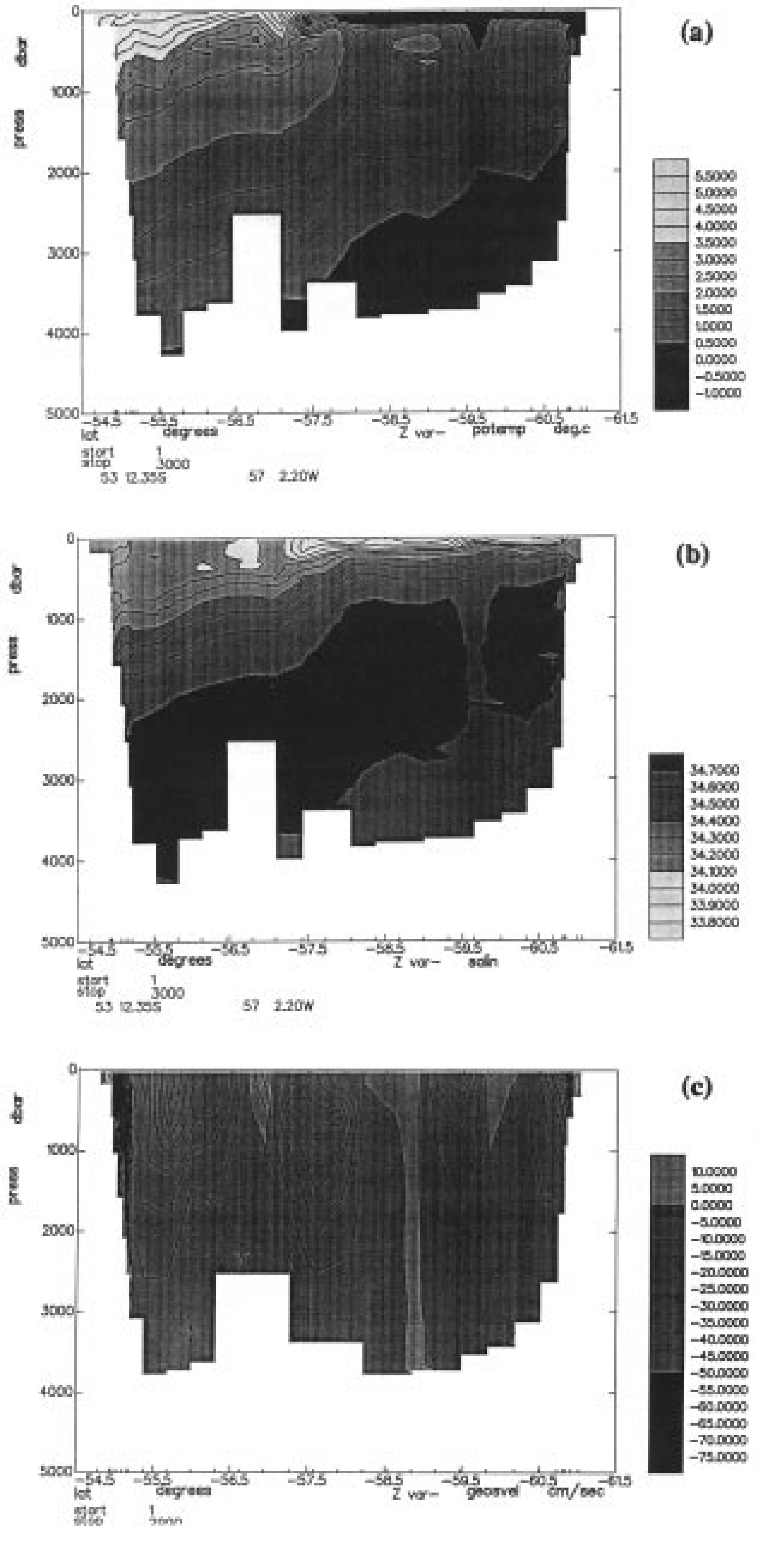

Figure 2. Sections of (a) potential temperature, (b) salinity and (c) geostrophic velocity relative to the deepest common level of station pairs.

with a maximum spacing of 1/3 degree latitude, and stations every 500 metres of depth change on the continental slopes at each end of the section (Figure 1). The Falklands/Malvinas Trough was ignored on the outward leg (apart from a test station), partly because rather little flow can reasonably escape over the sill between Burdwood Bank and South America, and partly because it had been thoroughly surveyed on the Polarstern in January 1993. As it happened, favourable ice conditions during the logistics phase of the cruise meant that time became available at the end for five stations to be occupied north of Burdwood Bank, during the night of 17/18 December.

Hydrographic observations were made with the BAS NBIS CTD, which had been calibrated by IOSDL before the cruise. The instrument is not equipped with an oxygen sensor and interface, and in any case neither time nor expertise was available on board to draw and analyse oxygen samples. The sample dataset consists of salinity samples drawn from the twelve 2.5 litre GO Niskin bottles, plus a number of temperature and pressure measurements from SIS digital reversing instruments. Salinity samples were analysed on board using a Guildline 8400 and batch P120 of Standard Seawater. The rms difference of duplicate samples drawn from 69 pairs of Niskin bottles closed at the same depth was 0.0008.

The hydrographic data (Figure 2a,b) have been used to calculate geostrophic velocities relative to the bottom (Figure 2c). The Subantarctic Front and Polar Fronts are immediately apparent, and the Polar Front appears to be just resolved into two distinct fronts, as discussed by Read et al. (paper submitted to JGR, see also a note in Sigma, Number 12) for their much better-resolved SeaSoar dataset. The total volume flux arising from the velocities in Figure 2c is 135 Sv, with 55 Sv north of and including the SAF and 48 Sv in the combined Polar Front. The Continental Water Boundary is seen at 60°50'S. Two substantial eddies are immediately apparent in the hydrographic data, at 57°05'S and 59°40'S. The first consists of water from well north of the Polar Front, displaced

Measurements in Drake Passage
James Clark Ross, November 1993

CTD	XBT
Sample Salinity	Underway Meteorology
ADCP	Underway Thermosalinograph

Differential GPS position (4 metre accuracy)
GPS 3DF heading (0.1 degree accuracy)

towards the Polar Front and so emphasising the front's upper ocean features; the eddy is located on the southern flank of a 2000 metre high feature in the seabed topography. The second eddy consists of relatively cold fresh water, apparently originating south of the CWB and found some 100 km out of place to the north. Intriguingly, very similar signatures can be found in the Discovery SeaSoar data, collected 12 months earlier.

The ADCP was run continuously throughout the cruise, with bottom tracking activated where the water depth was shallower than 500 metres. In general, good water tracking data were obtained to a depth of 150 to 200 metres at 12 knots. Although an initial calibration of the transducer misalignment was obtained from bottom tracking over Burdwood Bank, careful analysis of the ADCP data has been postponed until final navigation data are available.

As mentioned above, the ADCP measurements were supplemented with two items of GPS equipment, intended to greatly reduce errors in ADCP absolute velocities by reducing ship gyro error and ship position (and hence speed over ground) error. The Ashtech GPS 3DF (see also WOCE Newsletter 14, page 9) provided excellent measurements of ship's heading. The baselines for the antenna array were between 4 and 14 metres. T. Chereskin (UCSD) had told us that on the RV Thompson some adjustments to the factory default parameter settings in the receiver produced a considerable improvement in the data return. On the James Clark Ross, these adjustments also improved the data return considerably. Over the whole cruise, 95 percent of two-minute periods (two minutes was the ensemble averaging interval for the ADCP data) contained a good estimate of gyro error. Transient behaviour of the gyro error was now well resolved by direct measurement, removing the need for complicated interpolation schemes previously developed on RRS Discovery. Gaps in the time series of gyro error will be filled by linear interpolation.

The second strand of navigation improvement, believed to be previously untried on such a section, was to introduce Differential GPS position fixing. It was found that Signal Computing Ltd. of Guildford, UK, had established a DGPS base station in Stanley (amongst other sites) as part of a study of wide-area DGPS for Inmarsat. Signal Computing were contracted to provide IOSDL with compatible GPS equipment for the ship, to arrange the collection of data at the static station, and to post-process the two datasets with pseudorange DGPS corrections. For this trial study, real-time corrections were not considered feasible.

The preliminary results from this trial are very encouraging. The rms variation in ship position was found at three moored sites: at Stanley, a few kilometres from the base station, and at two BAS bases; Rothera, at a range of 1800 km, was the most distant. At all three sites, rms variation in position from the DGPS was 4 metres in each of latitude and longitude, with no apparent deterioration with distance from the static station over these ranges; uncorrected GPS positions had rms variation of up to 40 metres. The usefulness of the DGPS to enhance the quality of ADCP velocities at ranges of 200 to 2000 km will be assessed from ADCP bottom tracking data on the shelf each side of Drake Passage. The results of further study will be reported as soon as they are available.

The two PIs for the project, from IOSDL, were assisted in watchkeeping by BAS staff en route to Antarctic bases. They are particularly grateful to Mark Preston who provided CTD operations support.

In addition to the hydrographic work undertaken by IOSDL, the group from Proudman Oceanographic Laboratory recovered and redeployed moorings on the 1000 metre contours at each side of Drake Passage, and recovered a module of data from the pop-up system MYRTLE (see also WOCE Newsletter 14, page 41).

Acknowledgement

B. King was funded by a Fellowship in the Joint Environment Programme of National Power and PowerGen.

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Hydrographic Programme Data - a Status Report

Terry Joyce, Director, WOCE Hydrographic Programme Office, Woods Hole Oceanographic Institution, USA

The WOCE Hydrographic Programme Office in Woods Hole was the first WOCE Data Assembly Centre (DAC) to be established (in 1990). Three years on we can look at how well we are doing. WHPO 'data' is digital data of either station locations and times or CTD and bottle data. These data with their attendant documentation come from PIs and at the end of the WHPO involvement are transferred to the WHP Special Analysis Centre (SAC) in Hamburg. After the proprietary period is over, data are made available to the WOCE community on an ftp server.

The start of the path is the submission to WHPO of data sets and documentation by individual Chief Scientists. The WHPO usually re-formats the data and, in some cases, generates information files that are not otherwise available. Data are then sent out to a Data Quality Evaluator (DQE) for independent assessment of the quality. In the case of some repeat hydrography cruises, we hold a data set until we receive another one from the same group since it is as easy for a DQE to evaluate two data sets in the same region as one. Once the DQE reviews are complete, they are sent to the Chief Scientist, who is asked to revise his data set, (usually only by changing data flags or submitting additional information). The revised data set is re-submitted and, after further checking at the WHPO, is sent on to SAC and made publicly available once the proprietary period of 2 years elapses.

Station Inventory Summary

A summary of the one-time lines completed so far is shown in Figure 1; these include some pre-WOCE lines (asterisks) and one-time lines which may not fulfil the one-time survey requirements (question marks). In the latter case this is usually because the line did not go coast-to-coast, or has large gaps between stations. We look to the Core Project Working Groups to decide if the requirement has been met. Here we present a summary of the stations taken by each country for both the one-time and repeat hydrographic lines.

The station total includes all planned or reported WOCE stations taken excluding pre-WOCE data. If a line has an estimate of the planned number of stations AND we have a record of the actual number of stations, we can calculate a 'success' rate, the percentage of actual vs. planned stations. We also estimate the total reported stations vs. the total expected for all the cruises. This is a measure of the degree to which different countries are submitting some kind of 'digital' data. Figures 2 and 3 show the summary by country, for the one-time and repeat survey lines. The one-time lines are dominated by US efforts in the Pacific. The totals include data sets for which we only have estimates of total number of stations (assumed). Generally, the success rates are in the range of 80-110%. (The 'Russia' line is the joint US/Russia line S4). The repeat hydrography summary shows large numbers of stations by Japan, Germany, and the Peoples Republic of China. While the number of planned stations by Japan and PRC is high, we have received only a small fraction of the data so

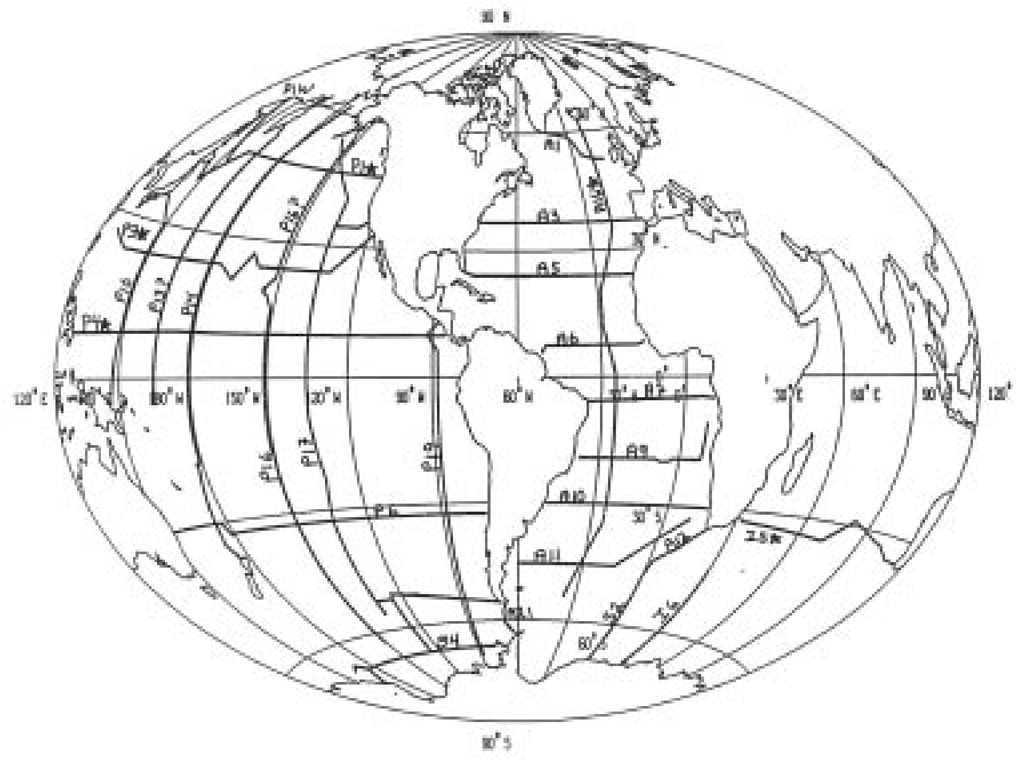

Figure 1. WHP Completed One-Time Surveys.

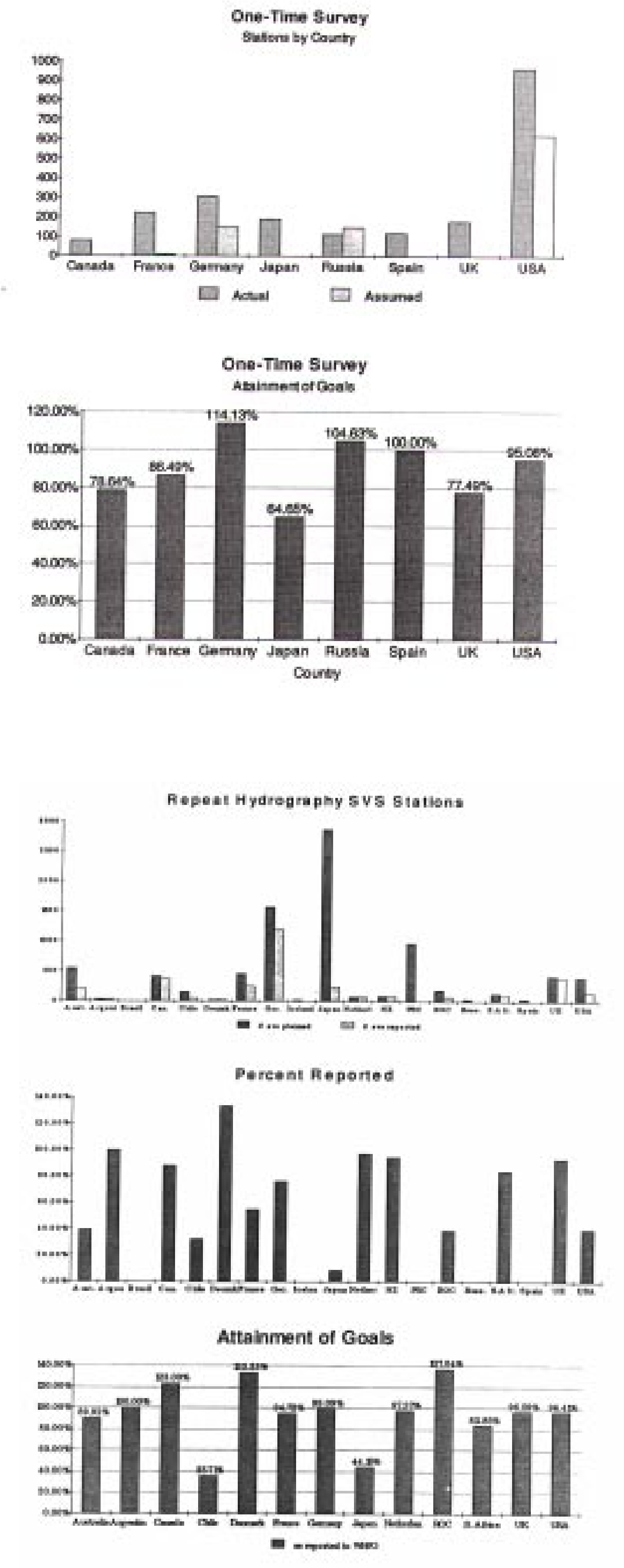

Figure 3. WHP Repeat Surveys - by Country.

far (none from PRC). On the positive side, more than a few hundred stations were reported to WHPO by about 6 countries, of whom Canada, Germany, and the UK are exemplary in their correspondence of planned and subsequently reported SVS. While small in size, the contribution from ROC surpassed its goals by a record 37 percent. The interpretation of these statistics needs to be done with care and discussion of any apparent anomalies should be taken up with the WHPO.

How to Increase the Rate of Data Submission

We are concerned that while some PIs are doing very well others are not. A US SSC *ad-hoc* committee on WHP data flow recently made recommendations of ways to improve matters. Some of these involve action by NSF and the US SSC and are beyond our purview. Those suggestions dealing with the WHPO point out areas in the US scheme where the WHPO could act to speed up or better facilitate data flow. We expect that many of these suggestions are relevant to the global community involved in the WHP. The primary slow point is the initial submission of cruise data to the WHPO. We will be contacting Chief Scientists and PIs for a limited number of cruises to see where the problem lies. A second point is access to preliminary WHP data by all PIs on a cruise, and a third deals with assembly of shorebased tracer data. The following are our responses to the US *ad-hoc* committee recommendations. None of them has been approved by the WHP Planning Committee and they will certainly be discussed prior to implementation. We present them here to provoke a wider distribution of our response to the review initiated by our funding agency for this WOCE facility.

Flexible formats

Over the course of time, data submitted to the WHPO are getting closer to what we request. The important thing is that the information we need is there: it is not so critical if the columns are switched or in some different order than suggested. Given the proper information (*e.g.*, laboratory temperature for nutrients), we have even been able to carry out conversions from concentration (*e.g.*, ml/l or μmol/l) units to mass units (μmol/kg). Important, however, is an evaluation of data quality by the PIs; this we cannot do. The procedures in our data manual, WHPO 90-1 (presently being revised) perhaps appear overly rigid, but if we do not ask for the information, we can't be surprised when it is not there. Chief Scientists who are now putting together data for submission to the WHPO, and who need assistance, should contact us for help or advice.

Access to proprietary data

We have been doing this (with the 'written' permission of the Chief Scientist), but recognize that we should be more proactive in making sure that PIs have the most recent copy of the data from their own cruises. Often cruise data are not transmitted to cruise PIs by the Chief Scientist at the time of the 'official' transmission to the WHPO. When a data set is submitted to the WHPO, we will make sure it is in our format and then make it available over the network to any PI from the cruise designated by the Chief Scientist for password-protected access.

Shore-based data

The Chief Scientists should not necessarily have to handle these as they can come to the WHPO direct from the PI (perhaps for several cruises) if properly indexed with the cruise data. Chief Scientists could be relieved of the chore and attendant anxiety of doing this 2 or more years after the cruise if they so desire; in that case they should delegate responsibility for submission of shorebased tracer data (here we exclude nutrients and CFCs, which are measured on the cruise) to the appropriate PI and make it clear to the PI(s) AND the WHPO who will be submitting shorebased data to the WHPO.

Summary

We already have a great deal of data in hand and there is much more to come. We are working hard to improve the data throughflow and our interactions with Chief Scientists and PIs. The success of WOCE in obtaining a truly global hydrographic data set will depend on the establishment of procedures for data submission and verification that are acceptable and workable for the whole community and we are working towards this.

The WHP Special Analysis Centre

Kai Jancke, WHP Special Analysis Centre, Hamburg, and Ilse Hamann, WOCE IPO

The WHP-SAC is a joint operation between the Max Planck Institut für Meteorologie (MPI), the Deutsches Klimarechenzentrum (DKRZ), the Institut für Meereskunde, Hamburg (IfM), and the Deutsches Ozeanographisches Datenzentrum (DOD) at the Bundesamt für Seeschiffahrt und Hydrographie (BSH). The SAC serves the WOCE community with 2 major objectives:

- to ensure data distribution to both the scientific community and the World Data Centres in a timely fashion,
- the production of "value added" datasets from which WOCE scientists can
  - (1) derive the mean oceanic state
  - (2) investigate the short-term variability in the ocean circulation
  - (3) provide a consistent oceanic data set to verify ocean models.

Composite datasets compiled by the WHP-SAC will be gridded datasets in a statistical sense. This task is to be done jointly by DOD and MPI with input from IfM.

Structure of the SAC

The DOD serves as the national archive for oceanographic data. It has extensive experience in the quality control, archiving, and retrieval of hydrographic data. The DOD participates in the IODE system of IOC and hence contributes to the worldwide data exchange via the World Data Centre system. DOD acts also as a data assembly centre for national monitoring programmes and as the national focal point for JGOFS data. The necessary hard- and software to handle large datasets is available at DOD.

The SAC has access to all computer facilities at the BSH. We use the CDC Cyber 960 with 20 Gbytes of disk storage running NOS/VE, 1 Terabyte of tape robot storage, terminals and PCs connected to the mainframe and printers and plotters. The system is connected to the German WINnet, from where there are gateways to the Internet. A Hewlett Packard workstation dedicated to SAC tasks is now operational at BSH. It connects to the main computing

Hydrographic observations are one of the primary observational tools within WOCE. As part of the WOCE Hydrographic Programme (WHP) the Special Analysis Centre (SAC) is responsible for the last two steps in the processing of the hydrographic data: the homogenization of the (quality-controlled) 'Level-II' data and the optimal as well as the dynamical interpolation of the 'Level-III' data.

facilities of BSH and to Internet. A Sybase data base management system is presently being developed in cooperation with WHPO on the workstation. MATLAB has also been installed as an additional data analysis tool for test purposes to compare with PV-Wave software.

The DKRZ is the central computer centre for climate research in Germany. It owns four supercomputers (Cray 2S, Cray YMP 4E, Convex C880, and Convex 3220 FS) and will install a Cray C90 in April 1994 and so can sophisticated ocean general circulation models. Furthermore, the DKRZ maintains a model support group of ten people (5 scientists and 5 programmers) experienced in running ocean models and in advising scientists to run models.

The IfM is the Physical Oceanography Department of the University of Hamburg. PIs at IfM have considerable experience in the analysis of hydrographic data, including quality control of individual and the homogenisation of a variety of data sets, for example from the North Sea.

The MPI has a long history in developing and applying climate models. Of particular importance for the SAC are the following global ocean general circulation models (OGCMs):

- the Large-scale Geostrophic (LSG) model (Maier-Reimer and Mikolajewicz, 1992),
- an isopycnic OGCM (OPYC) (Oberhuber, 1992), and
- a primitive equation model (HOPE) (Latif *et al.*, 1993; Wolff and Maier-Reimer, in press).

Furthermore, a variety of assimilation schemes were developed at MPI, such as a successive correction scheme or the 'adjoint' of the LSG model (Giering and Maier-Reimer, in prep.).

Operational setup

The data flow in the WHP, after dataset assembly in Woods Hole, runs as follows: the data are transferred cruise by cruise to the SAC and stored in the database system jointly developed by WHPO and WHP-SAC. Printed Cruise Reports are distributed by the SAC to the WOCE community. In accordance with the data sharing policy of WOCE, quality controlled datasets are also sent to WDC-A for final archiving.

Within the SAC database system, retrieval procedures extract subsets of the data for consistency checking. At present this is done by θ-S analysis (see, for example, Qiu and Joyce, 1992), multi-parameter water mass analysis (Tomczak and Large, 1989) and the analysis of repeated sections/stations. After consistency checking the data are sent to the MPI component of the SAC for assimilation.

The products of this first phase of consistency checking are plots and, to a limited extent, data sets gridded with optimal interpolation techniques. The gridding is done by an orthogonal surface analysis programme using multivariate trend surface techniques developed at BSH. The fields and residuals are given for all gridpoints. These gridpoints can be chosen in a flexible way by the operator of the computer program. If applied with the same grid geometry for repeated sections the variation in time can be plotted.

> ### Goals
>
> The SAC has three main goals:
>
> (1) To derive the main oceanic state.
> (2) To investigate the short-term variability in the ocean circulation.
> (3) To provide a consistent oceanic data set to verify ocean models.

After collection of all WOCE data from a particular ocean basin the SAC (DOD component) hopes to be able to produce gridded data in 3 dimensions for the basin in question. Plans are to use the optimal interpolation methods as given in the recent Southern Ocean Atlas by Olbers, Gouretski, Seiβ and Schroeter (1992). Outside scientists will be able to access all data for their own gridding purposes.

At present the SAC holds 11 datsets, all of which are past the proprietary period of 2 years after collection and are therefore publicly available via anonymous ftp. The ftp server name is ftp.dkrz.de (136.172.110.11). The login username is "anonymous" and the password is the email address of the user logging into the system (should the ftp program misbehave, try again starting the password with a hyphen or minus sign immediately followed by the email address). WOCE related data are found in the directory /pub/woce. By downloading the file README from this directory the user will be able to obtain all information necessary to browse the inventory of the SAC ftp server and to transfer datasets from the SAC to his local machine. An up-to-date list of data available can be found on the SAC ftp server in the file /pub/woce/ls-lR.

Datasets presently available on the SAC ftp server include repeat sections (CTD and bottle data) from the WOCE period (PR11, PR13N) between Australia and New Zealand (done in 1989 and 1990), and AR7E along 57°N in the Atlantic (1991). Data from the Hawaiian Ocean Time Series station (PRS2) will be transferred to the server shortly. Other high quality pre-WOCE datasets available on the server are the meridional North Atlantic section across the eastern basin, equivalent to A16 (1988), the zonal "heat-flux" section in the Indian Ocean along 32°S (I5, 1987), and the zonal crossings of the subtropical and subpolar gyres in the North Pacific of 1985 (P3 along 24°N and P1 along 47°N), as well as the 10°N section between the equatorial Pacific and the subtropics (P4, 1989). The next dataset to be expected on the server is the SAVE data.

Other types of value added datasets will be created jointly by MPI and DKRZ by using dynamical interpolation of the homogenized data sets provided by the SAC. It is planned to use first the 'adjoint' of the LSG model in its 5° x 5° version. The effective resolution, however, amounts to about 3.5° x 3.5° because the LSG model is formulated on a staggered grid (Arakawa-E). A higher resolution version (about 2.5° x 2.5°) of the LSG model is currently in the test phase and will be used later. Furthermore, the 'adjoints' of the OPYC and the HOPE models are under development and will also be used in the dynamical interpolation of the hydrographic data to study the sensitivity of the results to different model formulations.

MPI will also use other *in-situ* observations, such as drifter, float, and tracer measurements. It is also planned to make use of increasingly available satellite datasets (*e.g.* from ERS-1 and TOPEX/POSEIDON). Satellite measurements of sea surface temperature, sea level, and the surface wind stress field are of particular importance.

Data assimilation methods are still evolving and some technical problems still exist. For example, in the derivation of the mean oceanic state from the hydrographic data because of the huge amount of storage and CPU time needed for this task, since the adjustment time scale of the deep ocean is of the order of thousands of years. Suitable techniques are currently in the test phase at MPI and will hopefully be ready when enough hydrographic data are available to start the dynamical interpolation.

Guest scientists participating in the activities of both branches of the SAC can be accommodated for visits of typical duration of the order of several weeks.

Product development at the SAC

The WOCE Core Working Groups and WOCE NEG have been asked by SSG to provide guidance as to what kinds of standard products are required by the community. The SAC will then try to introduce any product feasible that will enhance the value of the data and of the whole WHP.

For example, at the CP1-6 meeting it was decided to revive the concept of a South Atlantic (SAVE) analysis as a focus for SAC product development. It was suggested that the SAC should grid hydrographic data from the period 1982-1988 encompassing 10°N to 40°S and compare it with the Levitus compilation. Results of this work are going to be presented at the South Atlantic Workshop scheduled for August 1994 in Bremen. The SAC (DOD component) is presently preparing the software for 1° x 1° gridding of data using Owen's method. The gridded dataset will be available via ftp. A long-term WOCE goal is the synthesis of all field observations. For a "WOCE climatology" of hydrographic data, the simplest presentation may be in the form of atlases and CD Roms describing the WHP surveys of the different oceans (similar to the GEOSECS Atlases). These atlases might contain various analyses, for example, meridional heat, mass, and property fluxes for selected sections.

Funding

Funding of the SAC is guaranteed by the German Government through the 'Bundesministerium für Forschung und Technologie' and by the host institutions BSH, DKRZ, IfM and MPI. The funding includes the travel costs for several guest scientists a year.

Members of WHP-SAC

Prof. Dr J Meincke (IfM), Director
Dr U. Cubasch (DKRZ)
Dr R. Giering (MPI)
Dr V. Gouretski (MPI)
K. Jancke (BSH)
Dr M. Latif (MPI)

Of these Giering, Gouretski and Jancke are working full-time for the WHP-SAC.

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WOCE Modelling: The Updated Science Plan

David Webb, IOS Deacon Laboratory, and Ilse Hamann, WOCE IPO

In the past year the Numerical Experimentation Group of WOCE (NEG) reviewed the progress made in the research required to achieve the key modelling objectives of WOCE, *i.e.* to develop ocean models for predicting climate change and to develop methods for analysing the WOCE field data. The NEG produced a Science Plan containing condensed information on how the great intellectual and technical challenges might be met by ocean modellers; it also tries to provide advice for scientific administrators who are faced with having to make judgements on the allocation of resources for which great competition among a variety of oceanographic projects exists.

The Science Plan discusses the underlying problems in developing models for climate research and arrives at a strategy for modelling in WOCE, aiming for a maximum in realism in the models. Work on a whole suite of models needs to continue and be intensified, for example on small scale process models, high resolution regional and global models, and global coupled ocean-atmosphere models.

Equally important is further development of schemes for the assimilation of the WOCE field observations into composite datasets. Techniques include inverse methods to produce an instantaneous best fit to a combination of synoptic data, adjoint methods for a best fit to data taken over an extended period of time, and sequential estimation techniques which assimilate non-synoptic data in an ocean model that runs only forward in time. Besides being used to intitialise models, the WOCE datasets will also serve to test models and to study the long-term changes in the ocean circulation.

The WOCE NEG acknowledges the progress made since the beginning of WOCE, but summarizes the remaining necessary improvements in ocean models as follows (taken from the WOCE NEG Science Plan for Ocean Modelling, WOCE Report No. 112/94):

❒ Development of improved high-resolution global ocean models and their use to study the present circulation of the ocean, the physical processes affecting climate change and the ability of the models to represent the key processes involved.

❒ Development of limited area high-resolution process models to improve our understanding of the processes affecting the ocean's impact on climate and to improve their representation in global ocean models.
- Areas of particular importance are the oceanic mixed layer, air-sea fluxes, sea-ice, deep convection, bottom water formation, overflows between ocean basins and mixing within the ocean.

❒ Development of more accurate global fully coupled models, the validation of such models using the high resolution models and the small scale process models and the use of such models to study the circulation of the ocean, its variability and effect on climate change.

❒ The huge size of the oceans and the limited amount of data available make the WOCE data assimilation problem particularly difficult. The WOCE NEG:
- calls for further fundamental work on data assimilation methods and would like to attract more groups to enter the field.
- promotes the preparation of a detailed plan for the assimilation of WOCE data to produce global fields for the study of long term changes in ocean circulation and for the initialisation and validation of ocean models.

❒ Finally to aid the development of both better ocean models and data assimilation methods suited for use with oceanic data sets, the WOCE NEG:
- would welcome the setting up of operational oceanographic analysis and forecast centres. As part of their work the centres should identify problems with the models and data assimilation methods and should work closely with the research groups to develop new and better schemes.

As modellers are actively pursuing aspects of the recommended work, the WOCE NEG has entered a phase of stronger interaction with other modelling groups, WOCE committees and related scientific programmes. For example, the eighth meeting of the WOCE NEG was held back-to-back with the fourth session of the Steering Group on Global Climate Modelling (Sidney, Canada, 13-17 September 1993), and in the future the WOCE NEG and WHP committees plan to have one of their members attend each other's meetings. The WOCE SSG encourages efforts to bring together observationalists and modellers, *e.g.* by organizing joint workhops. Several recommendations of the last SSG meeting address an increase in communication and activity between modellers, analysts and observationalists (see WOCE Report 116/94 of WOCE-20, 9-11 November 1993). NEG chair D. Webb participated in the second meeting of the CLIVAR steering committee (13-16 December 1993) and reported on the plans now being formulated by the CLIVAR SSG.

The TOPEX/POSEIDON Data

Carl Wunsch, Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, USA

A central idea leading to the proposal for WOCE was that satellite altimetry would provide a true global set of observations. In addition to being a central element of WOCE in its own right, such observations were an essential ingredient in rationalizing a field programme necessarily spread over many years. Altimetry would be the 'glue' of continuous global scale observations tying together the otherwise widely distributed (in space and time) *in situ* measurements.

Given the importance of altimetry in the planning for WOCE, it is highly satisfying to report, based upon the recent Toulouse meeting of the Joint US-French Science Working Team for TOPEX/POSEIDON, that this spacecraft is working at levels of accuracy and precision considerably exceeding the original design specifications.

The mission is the end-product of nearly 15 years of planning and struggle by the small group which set out in the late 1970's to obtain high accuracy global altimetric observations. The report of the TOPEX Science Working Group (1981) and the POSEIDON counterpart in France, called for a mission with a gross overall accuracy of about 13 cm (one number cannot characterize such complex measurements). Based upon the large number of analyses reported in Toulouse, it appears that accuracies of about 5 cm are being now achieved, and these will improve considerably in the near-future with modest corrections yet to be made to the data.

The GEOSAT mission, which provided the previous major altimetric data set, gave a misleading impression of the potential accuracy and utility of altimetry: the orbit error which so dominated the GEOSAT observations, made the data very difficult to use and gave rise to a large literature on how to make corrections. This error source is almost negligible in TOPEX/POSEIDON. The dominant time-dependent error in TOPEX/POSEIDON is the tides - representing inaccuracies approaching 5-10 cm in some places - even using the best tidal models prior to the mission. That the tide is the dominant error is very significant: TOPEX/POSEIDON is the best "tide gauge" ever available - the tidal error will be removed with ever-higher accuracy as mission duration increases. Several groups working on the tidal correction with TOPEX/POSEIDON data concluded that they expect ultimate accuracies approach 2-3 cm - which can be further improved by simple space/time averaging.

Figure 1 shows a one-year estimate of the absolute circulation, relative to an estimate of the geoid due to Marsh *et al.* (1990). All the known major features of the

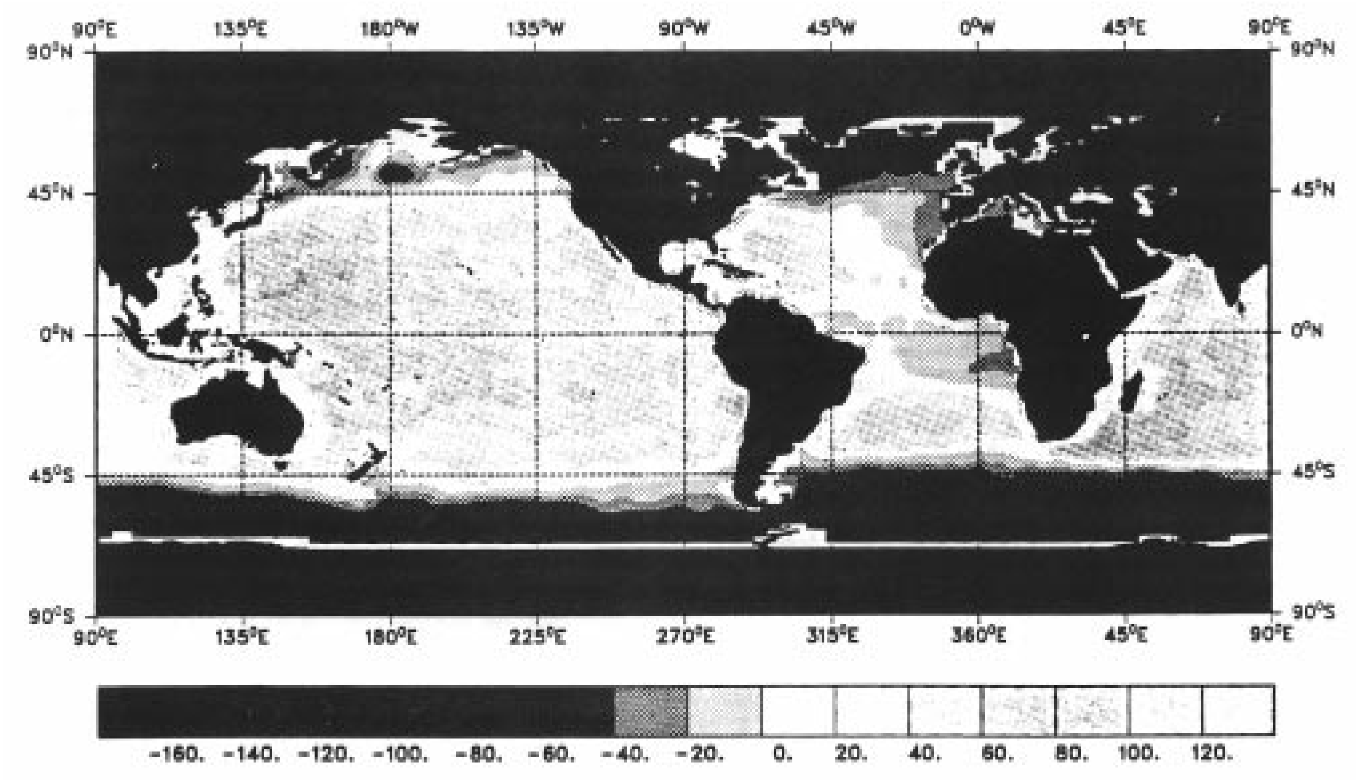

Figure 1. Absolute topography of the seasurface as a one-year average of T/P data relative to the Marsh et al. (1990) geoid estimate. Contour interval is 10 cm. The fields were filtered by expanding in spherical harmonics to degree and order 70.

ocean circulation are apparent: the subpolar and subtropical gyres of all oceans, the Circumpolar Current, the lower average Atlantic elevation, etc. The major residual problem is the geoid accuracy, and intensive effort is being made to remove them. To give some sense of the accuracy achieved, figure 2 shows the absolute elevation along two lines - one in the Indian Ocean at 32°S (Toole and Warren, 1993) and one at 28°S in the Pacific Ocean (Stommel *et al.*, 1973). Three curves are shown: the annual average from T/P relative to the Marsh et al. geoid; estimated absolute sea level from an inverse global circulation model based on hydrography alone (Macdonald, 1994); and the elevation from a three-year mean of the 1/4° resolution model of Semtner and Chervin (1992). Although the space/time averaging is not yet wholly consistent, we see that these three estimates, from extremely different methods, are generally within 10 cm of each other over entire ocean basins - a remarkable sign of progress in understanding ocean circulation in the past decade.

Time dependent motions are almost independent of any geoid errors (there are some second order corrections). Seasonal anomalies can be constructed from the one-year average circulation. One sees the gross seasonal oscillation in sea level: the northern hemisphere high in northern autumn, and low in spring. Much of this signal is steric, but dynamical effects are visible in the tropics. Prior to TOPEX/POSEIDON, the best such maps were constructed from the sparse, and fragmentary global sea level network, making it impossible to observe most of the open ocean, and using data distributed over many decades to produce a distorted climatology.

Figure 3 is the rms variability from TOPEX/POSEIDON data over one year. Although earlier missions had produced similar results, these are sharper and more accurate. Much WOCE activity will probably be directed at comparisons between results such as Figure 3, and mooring and float data, as well as the eddy fields generated in the

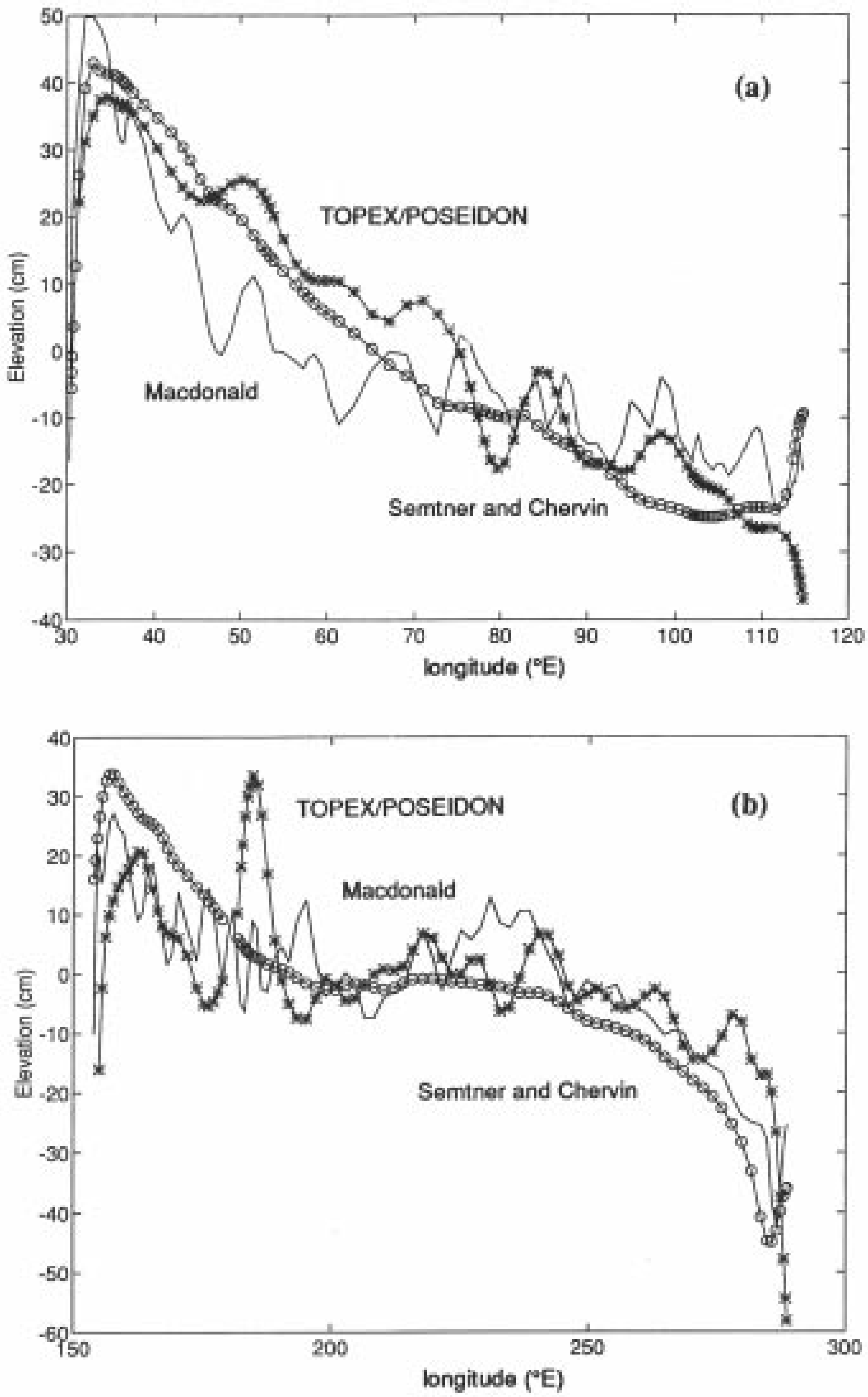

Figure 2. (a) Absolute elevation of the seasurface topography at 32°S in the Indian Ocean, from three independent methods: (1 The T/P data shown in figure 1; (2) from an inverse calculation of Macdonald (1994); and (3) from the $1/_4$° resolution version of the model of Semtner and Chervin (1992). A convergence of the estimates has clearly occurred at the < 10 cm level. (b) Same as 2(a) except along the "Scorpio" section (Stommel et al., 1971) at 28°S in the Pacific Ocean.

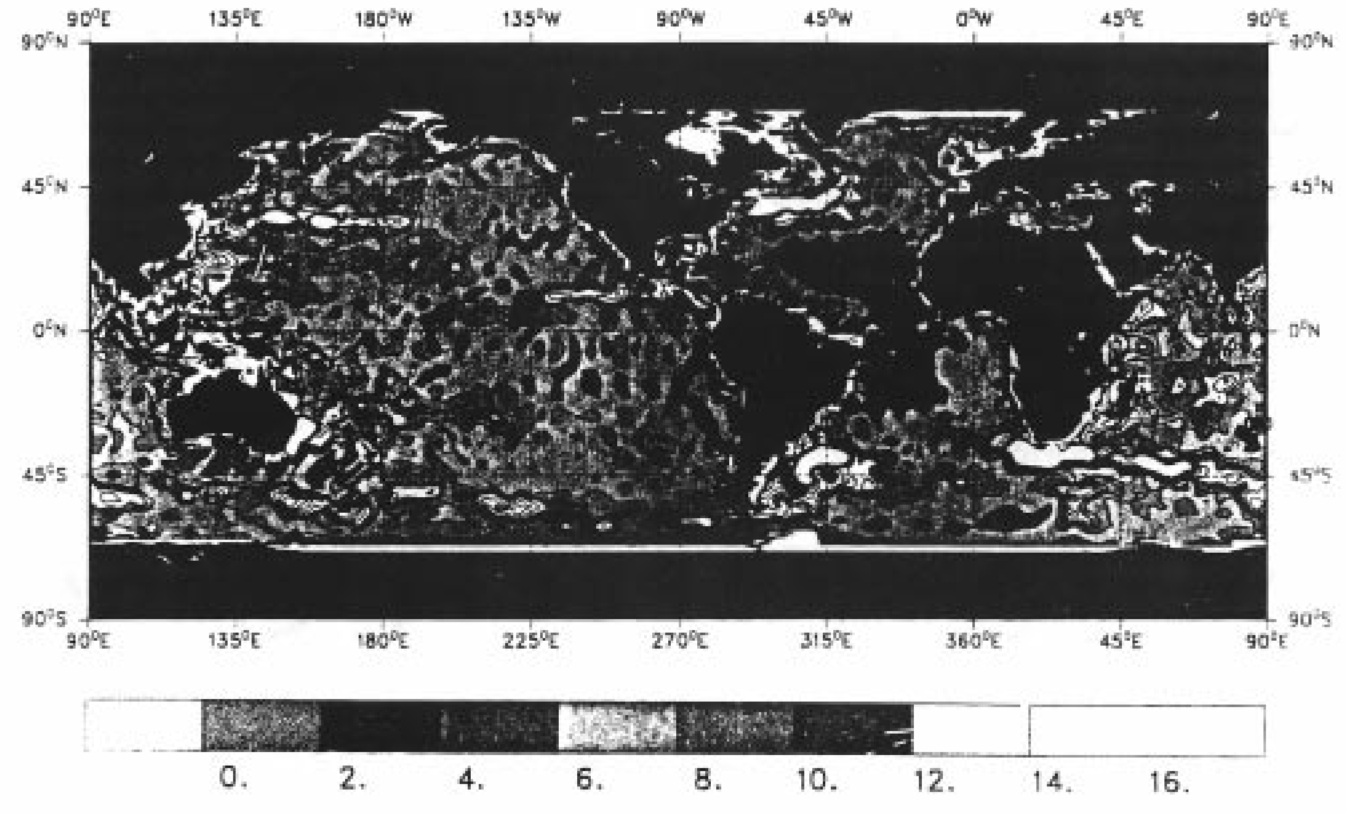

Figure 4. Point-wise RMS variability in the T/P results showing the regions of intense eddy activity and current meandering. Contour interval is 2 cm.

present generation of high resolution general circulation models.

TOPEX/POSEIDON is an astonishing technical accomplishment - we are measuring the sea surface topography to point-wise accuracies of a few centimetres from 1300 km in space. The engineering and scientific vision of 1980 is fully vindicated. The results shown here are still preliminary, but show that for the first time, oceanographers have a true global observing system. The data are public - there are no restrictions on use or distribution, and we anticipate a torrent of scientific results over the next several years. For WOCE and for oceanographers generally, there are now several immediate priorities:

(1) To produce the most accurate possible data sets. Point-wise absolute accuracies near 1cm appear possible.
(2) To sustain the mission accuracy and data flow over the full hoped-for lifetime of 5+ years.
(3) To attempt to provide successor missions - will oceanographers be content in the future if observations like those from TOPEX/POSEIDON cease to be available for understanding of the ocean circulation and climate change?
(4) To induce space agencies to fly one of the several possible gravity missions. Such a mission would greatly reduce the final uncertainty of the absolute circulation from TOPEX/POSEIDON.

(I am indebted to Dr D. Stammer, MIT, for many of the results shown here.)

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New WOCE Underway Data Submission Procedures

Bertrand J. Thompson, WOCE DIU, University of Delaware, Lewes, USA

WOCE "Underway Data" are primarily associated with the Hydrographic Programme (WHP)[1]. High quality, underway measurements have both direct and indirect scientific and operational applications. Among them are the identification, movement and mixing of water masses, fluxes of fresh water, heat and momentum through the sea surface, and the synoptic determination of hydrographic and atmospheric frontal structures. These measurements are of importance for the recognition of possible aliasing effects in WHP sections. WHP underway measurements, particularly from ships cruising away from general shipping lanes in otherwise data sparse areas, also supplement routine measurements aboard ships-of-opportunity participating in the Integrated Global Ocean Services System (IGOSS) and the World Weather Watch (WWW).

Until recently, the fate of WHP underway data (surface salinity, XBT/XCTDs, bathymetry, meteorology, currents (ADCP) and gases) was not clearly addressed within the WHP nor within the WOCE Data Management System. Arrangements have now been made to assemble and preserve these data in existing or new Data Assembly Centres (DACs) or, in the case of ADCP data, by the responsible PIs. Gases are considered the responsibility of JGOFS.

Procedures established for the processing and submission of these data will be issued by the WHP Office (WHPO) early in 1994. The WHP Planning Committee has decided that underway data (except XBT/XCTD) for which a DAC exists, should be submitted to the WHPO as soon as possible after a cruise. The WHPO will then forward the data to the appropriate DAC. It is, of course, important that the underway data be well calibrated before submission.

Following are brief summaries of the arrangements for each type of measurement. Summaries of the availability of data from the DACs will be included in the WOCE Data Handbook also to be issued early in 1994.

Surface Salinity

The DAC resides in Brest France co-located with the Global Upper Ocean Thermal DAC. Preliminary instructions for data submission and information on products of the DAC were provided in WOCE Newsletter No. 14, June 1993. This DAC collects all salinity data and issues products including summaries of data holdings, climatologies and data location plots. Data are checked and returned to the PI together with standardized anomalies of individual observations. The products are presently available for the Atlantic but plans are to expand to the Indian and Pacific Oceans.

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XBT/XCTD

The procedures for submitting XBT/XCTD data are long standing within the IOC's IGOSS system with well defined procedures and an active WOCE DAC is in operation. PIs should therefore follow the IGOSS procedures for both near-real time and delayed mode data submissions. Guides[2,3] are available on the collection and exchange of XBT/XCTD data from the IGOSS Operations Officer who operates out of the Intergovernmental Oceanographic Commission (IOC) in Paris. XBT and XCTD data should not be sent to the WHPO, we suggest the normal IGOSS BATHY messages be used for initial submission and that delayed mode versions of the data be sent to National data centres who automatically forward XBT/XCTD data to other National and International centres, and therefore to the WOCE Upper Ocean Thermal DACs.

Contact: Tim Wright
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Bathymetry

The National Geophysical Data Center (NGDC) in Boulder, CO, USA has agreed to be the Bathymetry DAC. Instructions for submitting bathymetry data to NGDC are being prepared and will be issued by the WHPO.

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Fax: 1-303-497-6513

Meteorology

Florida State University (FSU) has become the underway Met. DAC. FSU collects, checks, archives and distributes all (underway) surface Met. data from WOCE vessels and moored and drifting buoys. Instructions for the submission of met data will be issued by WHPO early in 1994. The FSU operation is a combined DAC/SAC, which means that it also has a mandate to generate and issue fields and uncertainty estimates of surface fluxes of heat and momentum to serve as surface boundary conditions for numerical ocean models and to be validation tools for other flux products.

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ADCP

No arrangements have been made to quality control and assemble ADCP data. The WOCE Scientific Steering Group agrees with the WOCE Implementation Plan, and with International Council for the Exploration of the Sea (ICES) that it is premature to store all ADCP data in data centres. ICES has a set of proposed guidelines[4] for the management of shipborne ADCP data which are suggested for WOCE use. The SSG has recommended that a small group of experts be requested to develop guidelines for sampling strategy, ADCP set-up and quality control. This group is presently being formed by IPO and is expected to report to SSG in October 1994. DIU has been requested to ensure that all ADCP projects are tracked. The bottom line is that PIs are expected to retain their data, or continue to follow their national practices, document their projects and to share their data within the WOCE data sharing guidelines. Once the experts have completed their study, a new approach may be taken.

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Gases

The WHP/PC has decided that responsibility for underway gas measurements be vested in the JGOFS community.

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Submission of underway data from past cruises

Many PIs have reported that underway measurements were carried out on past cruises but we have little information of the fate of these data. We urge all PIs holding underway data to contact the DACs to make arrangements for the transfer of these data to the DACs. As stated above, data from on-going and future cruises should be sent to the DACs via the WHPO. The WOCE Data Information Unit (DIU) is ready to assist PIs and DACs in assembling the underway data that has been taken to date.

Contacts: Katherine Bouton, James Crease and Bert Thompson
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Internet: woce.diu@delocn.udel.edu
Fax: 1-302-645-4007

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4. ICES Guidelines for the Management of Shipborne ADCP Data. In: Report of the 19th Meeting of the WOCE SSG, Appendix 7. WOCE IPO Report 103/93, July 1993.

Miami Meeting Studies Low Nutrient Seawater

Paul Ridout, Ocean Scientific International Ltd., Wormley, UK

A recent workshop to review the availability of reference materials for marine chemical measurements discussed the use of Low Nutrient Seawater (LNS) in the analysis of inorganic nutrients in seawater. The workshop, held at the NOAA Atlantic Oceanographic and Meteorological Laboratory was attended by representatives of JGOFS, WOCE and QUASIMEME all of whom are involved in marine nutrient studies. Although some oceanographers can prepare a suitable low nutrient seawater themselves, it was recognised that LNS as produced by Ocean Scientific International Ltd., would meet the needs of all laboratories working in this field.

The need for LNS arises from the fact that most analytical techniques for nutrients are affected by the presence of seawater matrix salts. Therefore it is essential that all working calibration solutions are prepared in natural seawater. In continuous flow analysis LNS can also be used to check the extent of the ‘refractive-index’ blank.

LNS is prepared from natural filtered oceanic seawater and is available in 1 litre bottles. ‘One-shot’ smaller volume (50 ml) bottles will become available during 1994.

For further information please contact: Ocean Scientific International Ltd., Brook Road, Wormley, Godalming, Surrey, GU8 5UB, UK, Tel: +44 (0)428 685245, Fax: +44 (0)428 685075.

The Drifter Data Assembly Center

Donald V. Hansen, Cooperative Institute for Marine and Atmospheric Studies, University of Miami and Mark S. Swenson and Mayra C. Pazos, NOAA, Atlantic Oceanographic and Meteorological Laboratory, Miami

A drifter data assembly centre (DAC) was established at NOAA/AOML during 1988 in support of the TOGA Pan Pacific Surface Current Study. By mid-1991, this study had evolved into the WOCE/TOGA Surface Velocity Programme as investigators from many countries expanded the area of operation from the tropical Pacific to the entire Pacific basin and the North Atlantic. The DAC expanded its activities in step with the growing field observations. The objective of the DAC has always been to acquire data from cooperating operators of WOCE-qualified drifters for uniform objective processing to a unified research quality surface velocity data set. A preponderance of operators of WOCE-qualified drifters has elected to cooperate in this objective. The DAC also provides an ancillary service of managing the dissemination of data from buoys of US operators via the GTS, making them accessible for real time operational analyses.

Data from WOCE buoy operators can be accessed from the Service ARGOS Processing Center in Landover, Maine, USA, and Toulouse, France, by the DAC at any time, but this capability is used only to the extent necessary for monitoring the arrays or assisting special programs for which real time data are needed. Figures 1 and 2 are samples of a class of data products that are produced fortnightly in the DAC for distribution to cooperating investigators to facilitate planning of new releases, and to a small number of other interested agents such as the IPO and the DIU. Similar maps are produced for higher latitudes of the Pacific. The activity map for the tropical Pacific is provided also to NOAA/NMC monthly for publication in the Climate Diagnostics Bulletin. Near real-time data have been used to assist in special projects such as exploration of alternative fishing strategies for tunas, and

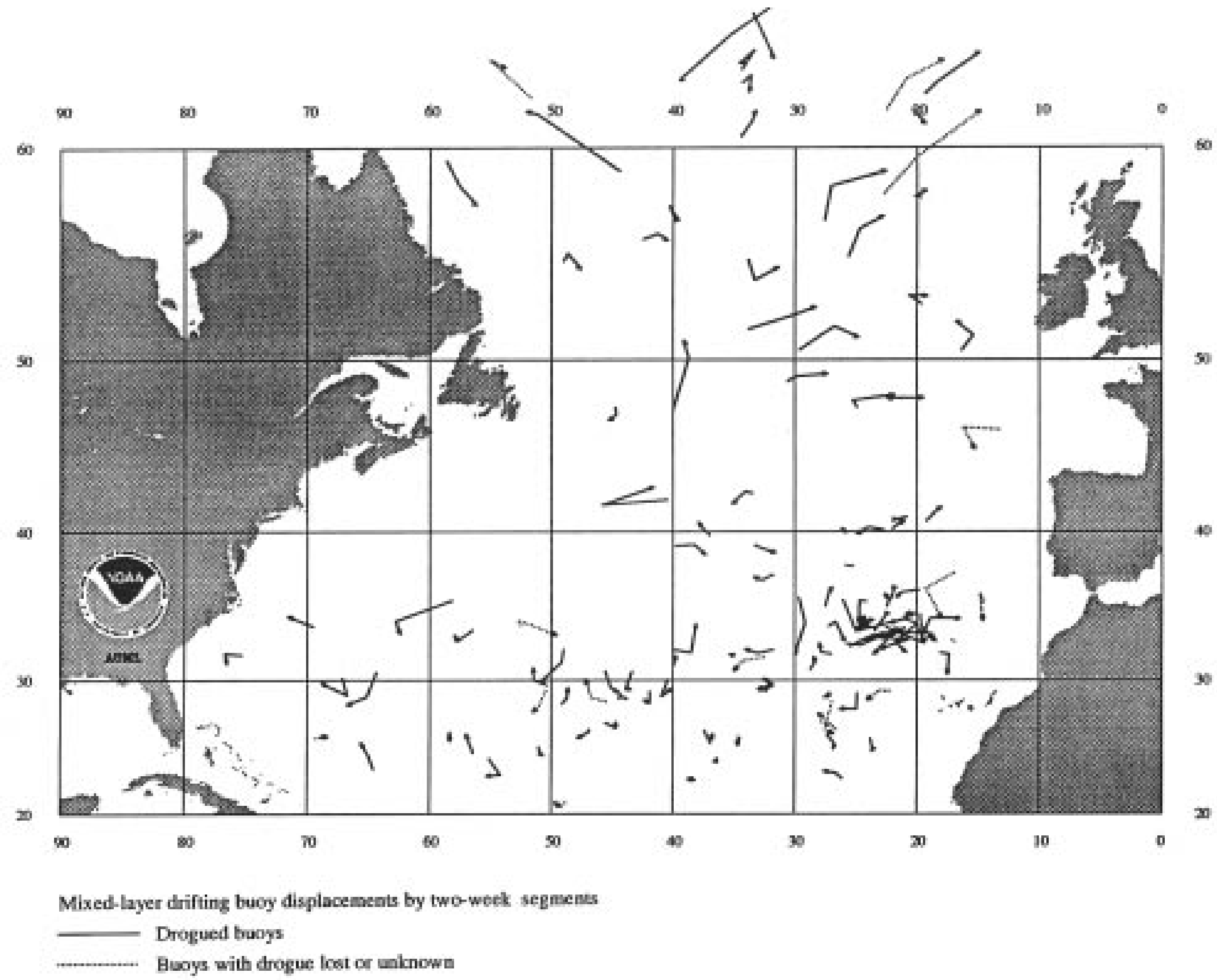


Figure 1. Fortnightly displacement map for drifting buoys in the North Atlantic Ocean.

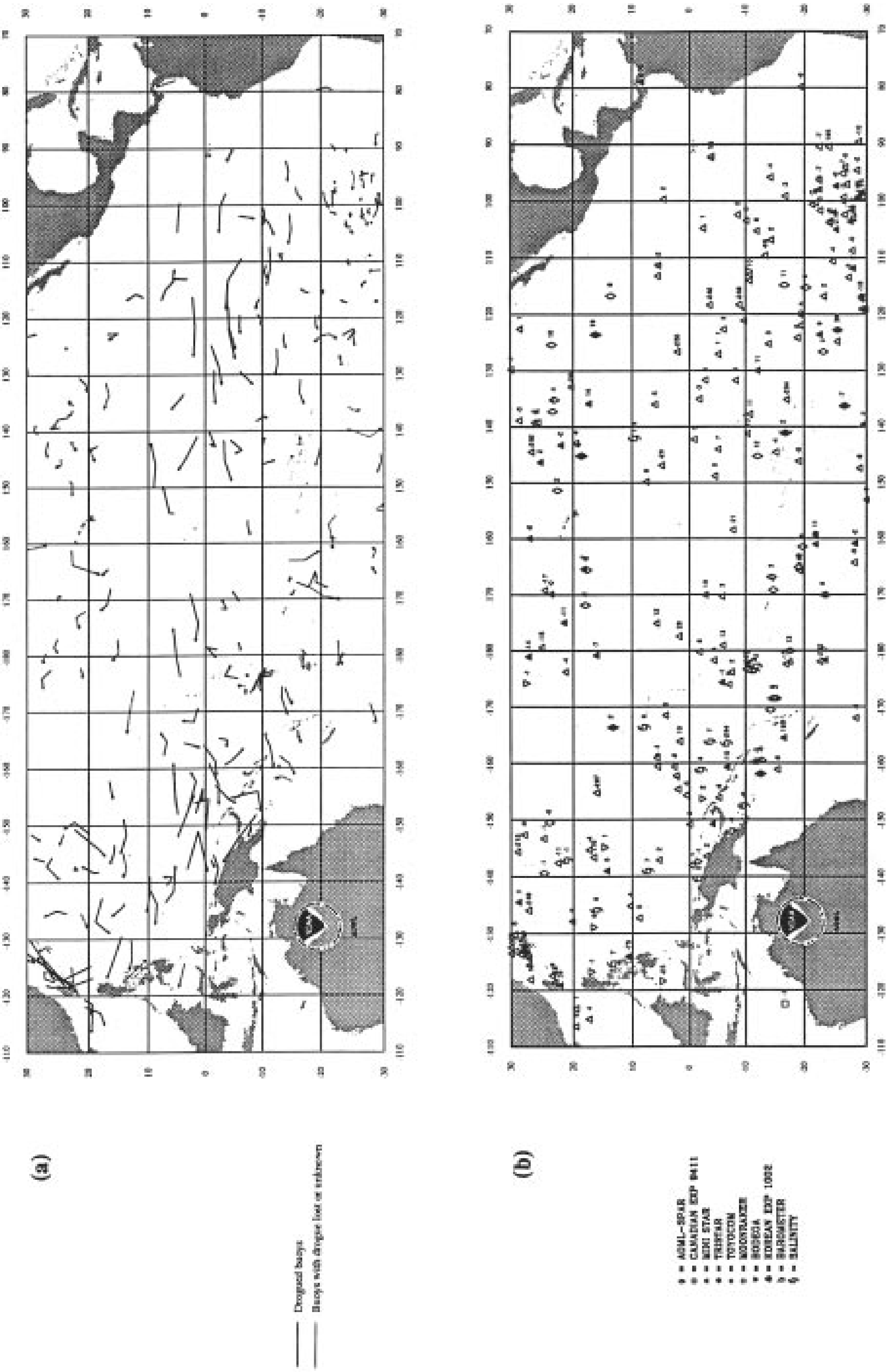


Figure 2. (a) Fortnightly displacement map for drifting buoys in the tropical Pacific Ocean.
(b) Fortnightly population/status map for drifting buoys in the tropical Pacific Ocean.

Table 1. Pre-WOCE Drifter Data (TOGA PAN-PACIFIC: 1/1/88-6/30/91)

PI		No. Buoys Reported	No. Records
Niiler	(US)	252	236988
Hansen	(US)	164	190064
Ishii	(J)	52	45480
Reverdin	(F)	39	33860
Richardson	(US)	32	36092
Collins	(US)	6	1492
Cresswell	(Aust)	5	600
Total		**550**	**544576**

Table 2. WOCE Data Period (7/1/91-9/30/93)

TROPICAL PACIFIC REGION (20°N-20°S)

PI		No. Buoys Reported	No. Records
Niiler	(US)	273	378948
Hansen	(US)	96	147288
Reverdin/du Penhoat	(F)	54	42404
Nakamoto	(J)	8	6476
Hu	(ROC)	5	1084
Ishii	(J)	2	272
Total		**438**	**576572**

NORTH PACIFIC REGION (>20°N)

PI		No. Buoys Reported	No. Records
Niiler	(US)	114	162376
Hu	(ROC)	53	32392
Thomson	(Can)	26	23300
Paduan	(US)	23	2764
Limeburner	(US)	21	7860
Lie	(S Kor)	9	2000
Total		**246**	**230692**

SOUTH PACIFIC REGION (<20°S)

PI		No. Buoys Reported	No. Records
Niiler	(US)	71	153820
Cresswell	(Aust)	13	16792
Jones	(Aust)	2	520
Total		**86**	**171132**

NORTH ATLANTIC REGION

PI		No. Buoys Reported	No. Records
Niiler	(US)	124	117056
Paduan	(US)	28	55180
Derek	(UK)	4	1736
Blouch/Rolland	(F)	3	2576
Total		**159**	**176548**
Total WOCE Period		**929**	**1154944**

the recent iron enhancement experiment. Electronic data acquisitions are used also for verification of buoy performance prior to release to GTS dissemination and for a cursory ongoing quality control.

Production line data processing is done on raw data received monthly from Service ARGOS, or in the case of buoy operators using local user terminals for data acquisition, from the individual investigator. Rate of change criteria are used to edit unlikely values from the position and SST records. Finally, an optimum interpolation algorithm is used to interpolate the intermittently sampled data to uniform quarter-day intervals. The basic sampling schedule for WOCE and TOGA drifters consists of "bursts" of one to six or eight satellite passes in 24-hour periods, separated by quiet periods of 48 hours duration. We have adopted a philosophy of rendering all possible interpolation data, even those from buoys which, due to infrequent successful transmissions, produce large uncertainties. The error estimates obtained from the interpolation procedure serve as a quantitative measure of the uncertainty of the more accurate data, and as a qualitative flag to the very inaccurate data. Signals from drogue on-off sensors are used to determine and record the status of subsurface drogues. A manuscript describing the data processing procedures in detail is in preparation for submission to the Journal of Atmospheric and Oceanic Technology.

Three levels of data are forwarded to the Canadian Marine Environmental Data Service (MEDS) for archival and distribution to general users. These are: the original raw data (positions and sensor data as received from Service ARGOS), the edited data file consisting of chronological files for which a median filter has been used to estimate a single value for each satellite pass and from which doubtful values have been excised, and interpolated positions and sensor values together with interpolation error estimates. When practical, special effort is made to assume that these error estimates are quantitative rather than just comparative; this is usually successful. The data submitted to the MEDS consist, for each buoy, of one-dimensional time series of latitude, longitude, velocity components, sensor values, and corresponding error estimates.

Data processing in the DAC is usually completed within a month of data receipt, which is within about six weeks following the end of each month. Processed data are forwarded to the MEDS at six-month intervals, a half year after the close of each six-month data window. Cooperating investigators are able to access any data in the DAC, but are encouraged to obtain from the MEDS any data that are available there. MEDS observes a two-year publication rights period for WOCE SVP data unless waived by the PI. Figure 3 shows schematically the data flow associated with the DAC.

As of the end of July 1993, the DAC had received and processed more than 1.5 million drifting buoy "records" from investigators in nine countries. Although the standard observing schedule for WOCE has been buoy transmission during 24 hours of 72, some operators have opted for more frequent transmissions, such as 24 hours of 48, eight hours of 24, or continuous transmissions during an initial period or all of their investigation. For simplicity, we count the interpolated data, *i.e.*, the number of records is four times the span of days during which each buoy was transmitting useful data. Our data receipts are summarized by source (country and PI) in Tables 1 and 2. (Back data have been received also from the Dutch WARP programme, but are not yet processed.)

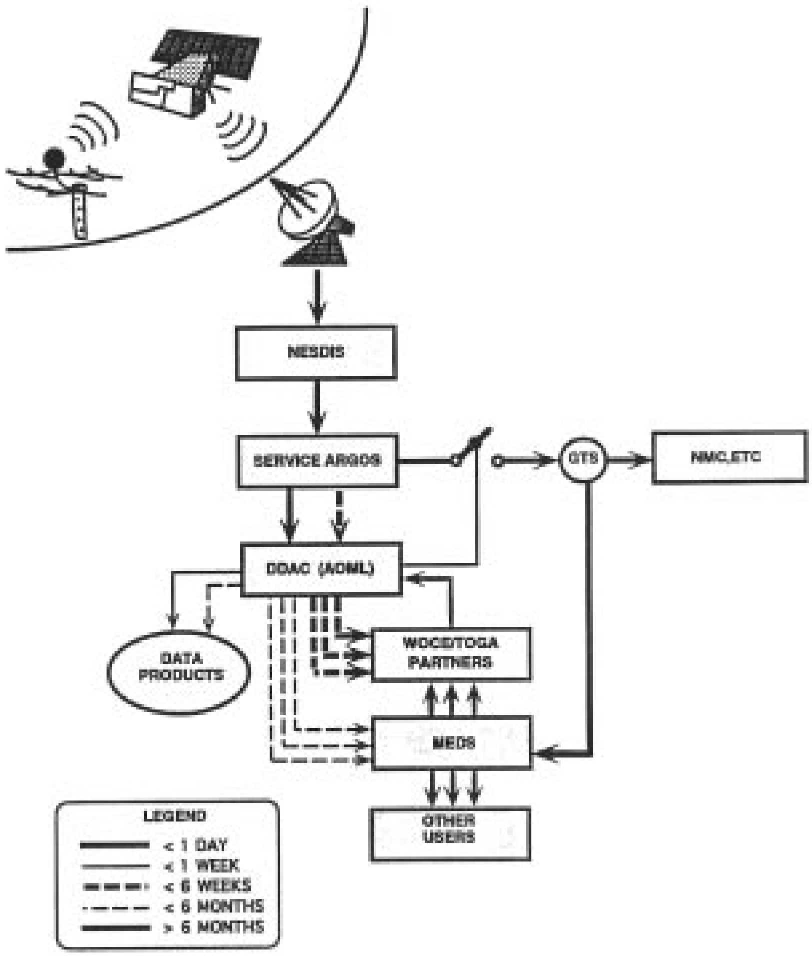


Figure 3. Schematic diagram of drifter data flow through the DAC system.

Acknowledgments

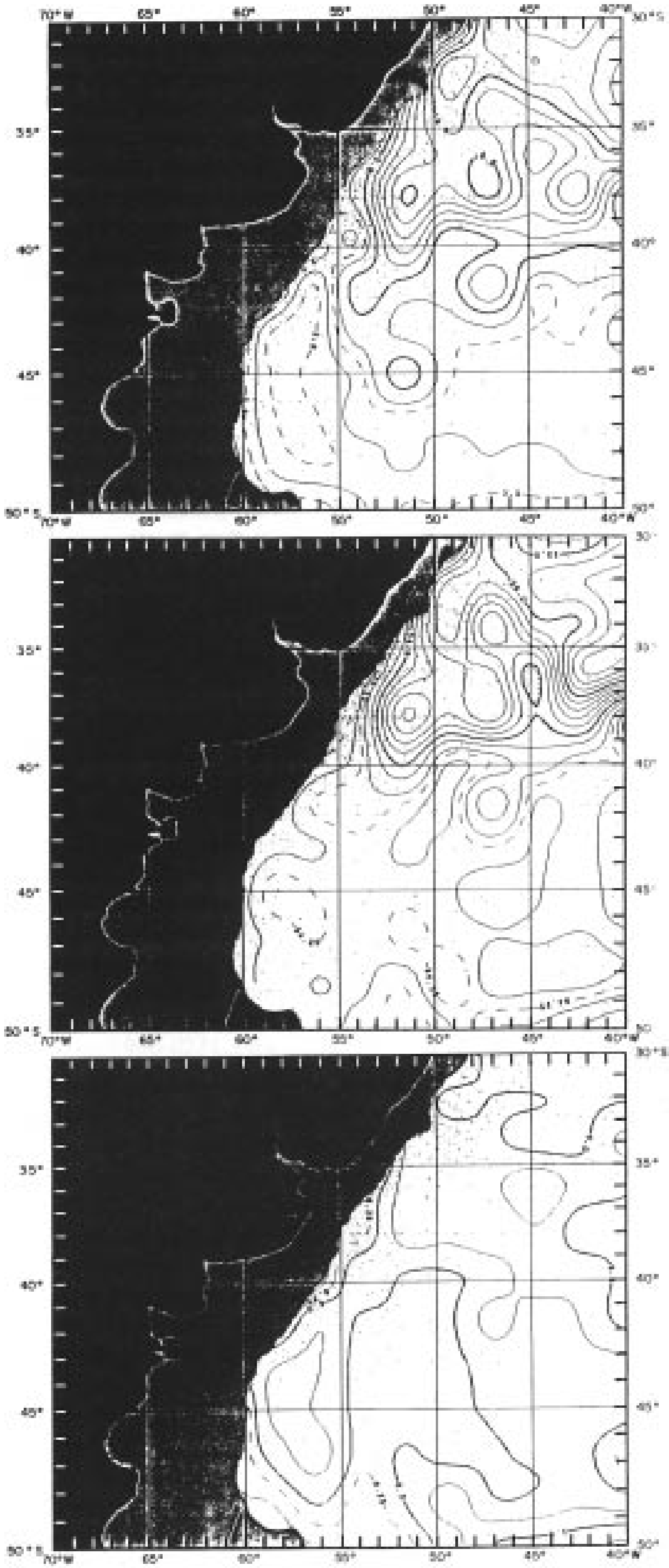
Operation of the DAC is funded jointly by the Atlan-

Oceanographic Atlas of the Western Argentine Basin

Alberto R. Piola and Omar A. García, Departamento Oceanografía, Servicio de Hidrografía Naval, Argentina

An Oceanographic Atlas of the Western Argentine Basin and the adjacent continental shelf has recently been published by the Servicio de Hidrografía Naval of Argentina.

The Atlas contains a graphical presentation of oceanic physical and chemical observations from the region bounded by 30°S and 50°S and 40°W and the coast of South America. The publication includes oceanographic data collected until early 1988. The data was obtained from the files of the Argentine Oceanographic Data Center and directly from several Principal Investigators. Data quality control was based on various data consistency tests as well as analysis of cruise by cruise temperature versus property distributions and preliminary horizontal distributions.



Horizontal distribution of potential temperature θ (°C, Figure 1), salinity S (PSU, figure 2) and dissolved oxyygen (ml/l, Figure 3) at 500 m. The contours are based on 1479, 1482 and 1175 observations respectively, and contour intervals are 1°C, 0.1 psu and 0.5 ml/l.

Quality control tests were passed by 5152 oceanographic stations collected from 52 vessels. The first station reported in the area was taken from RV Deutschland on 11 August 1911.

The data was interpolated to thirteen horizontal standard levels and gridded over a ~200 km x 200 km grid. The gridded data was objectively contoured.

Horizontal distributions of potential temperature, salinity, potential density anomaly, dissolved oxygen, silicate, phosphate, nitrate and Brunt Väisälä frequency at thirteen depths between the sea surface and 5000 m are presented. In the upper 250 m of the water column the horizontal distributions are presented in annual and semi-annual maps. Semi-annual maps are constructed for the periods May-October and November-April.

Potential temperature, salinity and dissolved oxygen distributions at 500 metres are shown in Figures 1, 2 and 3 respectively. Each map shows the station positions and the legends indicate the plotted variable, units, depth level, number of observations and contour interval.

Depth, potential temperature and salinity distributions are shown for selected density surfaces characteristic of the core of the major water masses. Dynamic topographies relative to deep isobaric surfaces represent the geostrophic flow patterns.

Potential temperature versus salinity diagrams over regions of 5° latitude by 5° longitude areas are also presented. Similarly, potential temperature versus salinity diagrams over horizontal surfaces for the whole region are given.

The project was financed by Consejo Nacional de Investigaciones Científicas y Técnicas and by Servicio de Hidrografía Naval (SHN) of Argentina. Publication costs were covered by SHN.

The data set is being updated and will be available in digital form in the near future.

The Atlas can be ordered through Departamento Oceanografía, Servicio de Hidrografía Naval, Av. Montes de Oca 2124, 1271 Buenos Aires, Argentina. Tel: 54-1-213091, Fax: 54-1-3032299.

Announcement of SVP Data Availability

Laurence Sombardier, Global Drifter Center, Scripps Institution of Oceanography, USA

The Surface Velocity Programme (SVP) has been working towards implementing a global system for measuring surface velocity, SST and air pressure for the past 6 years. A mixed layer drifter named the SVP Lagrangian Drifter, was developed for this purpose at the Global Drifter Center (GDC) at Scripps Institution of Oceanography. The SVP drifter has been progressively modified in order to develop and improve a specific set of qualities such as accurate water following capabilities, durability at sea, low cost, ease of manufacture and ease of deployment. The design was standardized in 1990 with the distribution of the WOCE/TOGA Lagrangian Drifter Construction Manual (Sybrandy and Niiler, SIO Reference No. 91/6, WOCE Report No. 63/91). The SVP drifter has a slip of less than 1 cm/s in winds of 10 m/s, its half-life at sea is over 450 days and it is routinely deployed from VOS vessels, research vessels and aircraft. Versions of this drifter are manufactured in the USA, Canada, Australia, France, Republic of China, Korea, Brazil and Japan.

The SVP drifter has a drogue centered at 15 metres depth and is tracked to within a 300 metre radius by Service ARGOS. A linear SST sensor accurate to 0.1° is located on the lower half of the surface float. The SVP drifter is fitted with a submergence sensor which allows the status of the drogue to be determined; the surface float of a drifter without a drogue will rarely submerge. A variety of other sensors (salinity, air pressure, air temperature) have been successfully adapted to the SVP drifter (WOCE Reports 87/92 and 111/94 of the SVP-5 and SVP-6 meetings, respectively).

Management of SVP field operations are organized into two main centers at three locations:

(1) the Global Drifter Center (GDC) at Scripps Institution of Oceanography is responsible for coordinating deployments and new technical developments,

(2) the Data Assembly Center (DAC) at AOML (Atlantic Oceanographic and Meteorological Laboratory) is responsible for collection and quality controlling the drifter data while the DAC at MEDS (Marine Environmental Data Service at the Department of Fisheries and Ocean, Canada) is responsible for disseminating drifter data to the general scientific community.

Systematic deployments in SVP started in 1988 as the Pan-Pacific Surface Current Study in the Tropical Pacific under the auspices of TOGA. Over 550 drifters have been deployed in that region since. Figure 1 shows the drifter tracks in the tropical Pacific from 1988 to mid-1993 in the form of a “spaghetti diagram”. WOCE deployments commenced in 1991 in both the mid-latitude Pacific Ocean and the North Atlantic Ocean. The total density of data collected is illustrated in figures 2 (for the Pacific Ocean) and 3 (for the Atlantic Ocean). Density on these figures is the total number of raw data observations on file at the DAC.

SVP is an international project with over 14 participating countries. Special projects such as the US Subduction project around the Azores, the US California Current study, and the Kuroshio study done by the Republic

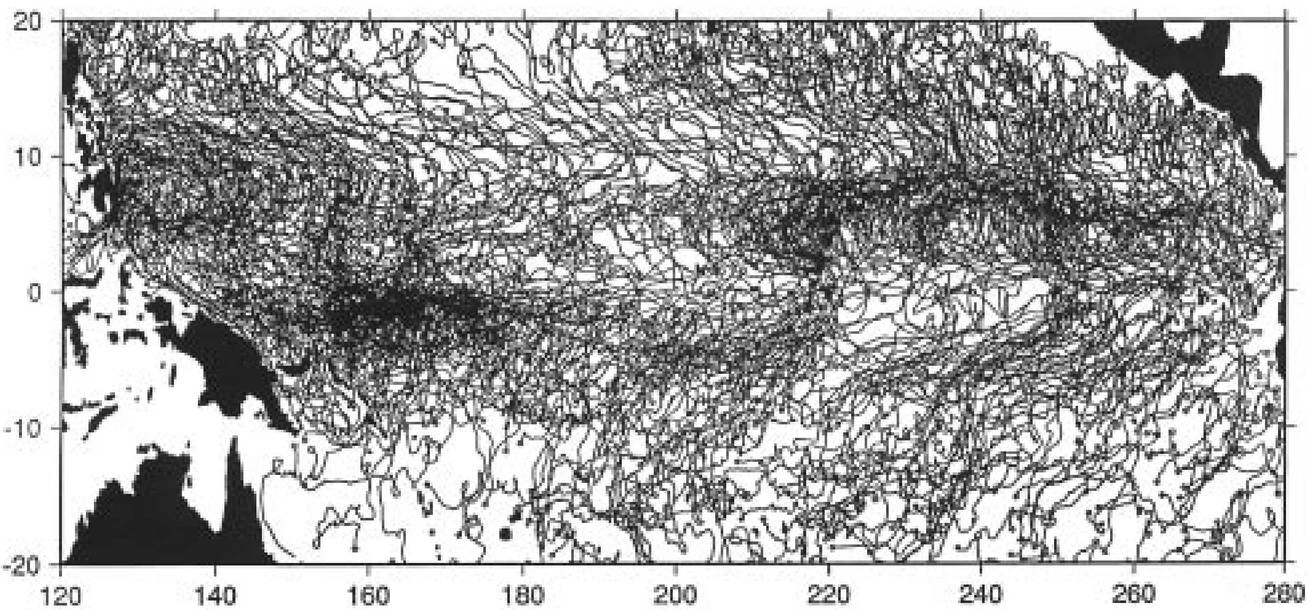


Figure 1. Trajectories of drogued drifters in the tropical Pacific from 1988 to mid 1993.

of China, contribute drifters to the open ocean arrays, although initial deployments are made in a smaller area and on a more frequent basis. The high density region in Figure 3 (dark shading) corresponds to the Subduction region; this array was implemented in 1990 whereas the rest of the Atlantic Ocean was implemented in 1991.

Drifter SST is broadcast in real time through the GTS and is thus available to all who have access to GTS data. The details of data flow through the drifter DAC system are described in D. Hansen's article (this issue of the WOCE Newsletter).

The drifter database at MEDS now contains data received from over 1500 drifters deployed in the Pacific and the North Atlantic Oceans and is expected to rapidly expand as drifter arrays in the Southern Oceans, Indian Ocean and South Atlantic Ocean are implemented in 1994. In addition to drifter position and sensor data files, MEDS is also archiving a Metafile put together by GDC and updated on a 6-month basis. This Metafile contains detailed engineering descriptions and calibration information for each SVP drifter contained in the raw and krigged data archives.

The TOGA drifter data have been available through MEDS since 1991 and have also been incorporated into the TOGA CD-ROM produced in 1992 (by TOGA ITPO). US WOCE data, along with the US TOGA data, are now available through MEDS. Interested parties should contact Andre Bolduc (Tel: 613-990-0231, Fax: 613-990-5510, Omnet: A.BOLDUC). In MEDS, data are filed under WOCE or TOGA data depending on the associated ARGOS Experiment Number. The most sensible way to request data is to specify a precise geographic region and time window of interest. Some international WOCE drifter data sets have a two year proprietary user list. All International TOGA data and some WOCE data received until now are generally available. MEDS has set up flags on these drifters to ensure that the data policy be respected. The largest data set for public access is from the Tropical Pacific (20°S to 20°N) as it now spans 5 complete years from 1988 to 1993.

For further information contact: Laurence Sombardier, Global Drifter Center, Scripps Institution of Oceanography, UCSD, 9500 Gilman Drive, La Jolla, CA 92093-0230, USA, Tel: 1-619-534-7520, Fax: 1-619-534-7931, Omnet: P.NIILER, Internet: laurence@nepac.ucsd.edu.

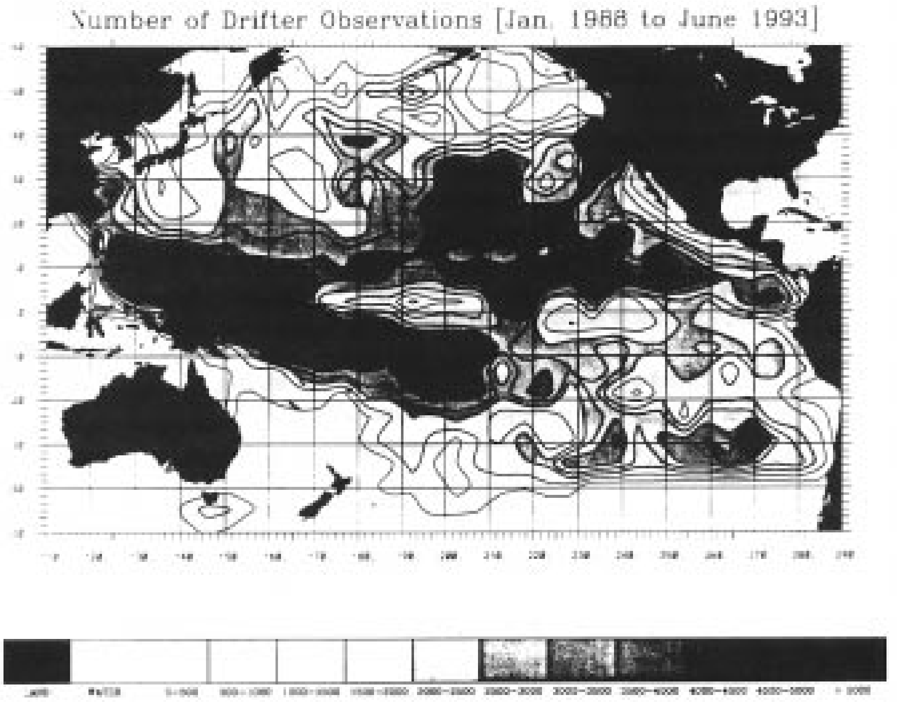


Figure 2. Number of drifter observations (1988 - mid 1993) in the Pacific Ocean.

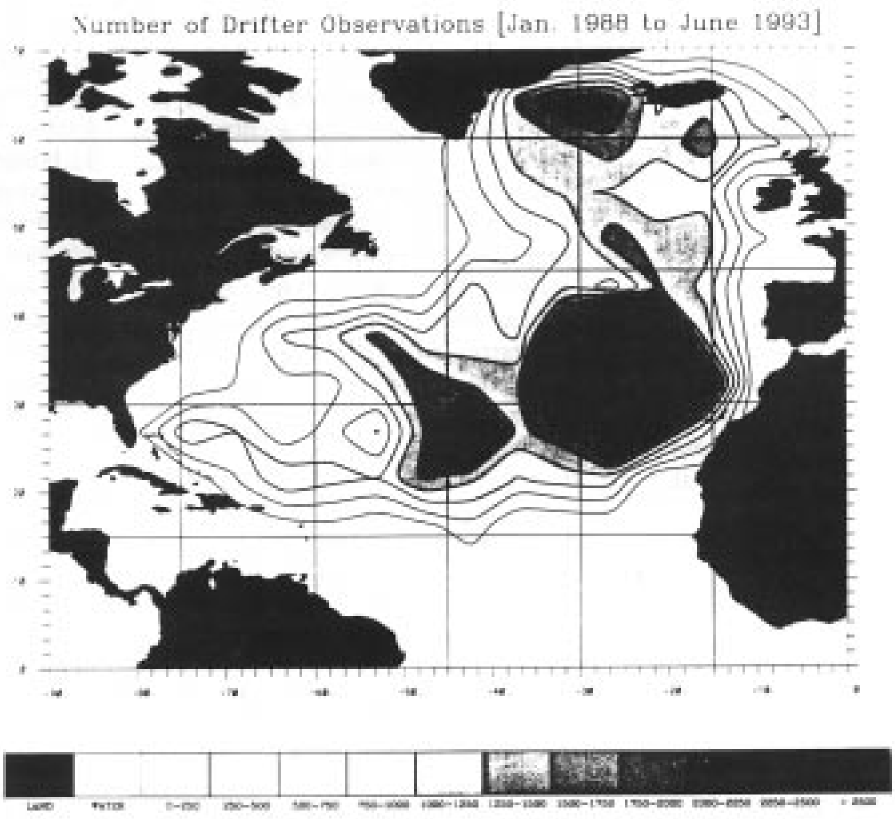


Figure 3. Number of drifter observations (1988 - mid 1993) in the North Atlantic Ocean.

Calibration of Temperature and Pressure Sensors for WOCE

T.J.P. Gwilliam and S.B. Keene, IOS Deacon Laboratory, Wormley, UK

Introduction

It has been estimated by researchers, that over the period 1990-97 some 25 years of ship time will be required to complete the WOCE hydrographic sections where the ocean variability is to be measured. With the international effort required to make so many measurements in this, at times, unfriendly environment, it is essential that expectations for data quality are consistent and realistic. To meet these expectations it is therefore essential that the calibration of the sensors used to make these measurements are also of the highest order.

With the guidance from the WHP Planning Committee, the specification produced by the WOCE Hydrographic Programme Office (WHPO: Joyce, 1988) covers all the standards for water samples including the specifications for temperature and pressure sensor calibration accuracy.

This paper describes the equipment and the techniques used at the Institute of Oceanographic Sciences Deacon Laboratory (IOSDL) in the calibration of the temperature and pressure sensors used for oceanographic measurements.

Expectation of temperature and pressure sensor calibration accuracy and precision is 0.002°C and 0.0005°C to the International Temperature Scale 1990 (National Physical Laboratory, 1989) respectively, for the former, over the range -2°C to +30°C, and 3 decibar (dbar) accuracy with 0.5 dbar precision over the range 0 dbar to 6000 dbar for the latter. The requirement for a 0.002°C accuracy is ambitious, and it is only essential for measurements taken in the deeper waters, where, over the temperature range 0°C to +5°C, the temperatures are relatively stable in time and space; to determine the absolute temperature where changes are in the order of millidegrees require this degree of accuracy. In the top 1000 metres, the temperature gradients are much larger and measurements to 0.005°C accuracy are quite acceptable. High accuracy temperature measurements are also important for the calculation of other parameters such as salinity, density, and water velocity as well as for compensating values from most other sensors which have an unwanted temperature sensitivity.

The temperature calibration facilities at IOSDL consist of two sections, the transfer standard laboratory where the thermometers and bridges are calibrated against known standards, and secondly, the instrument calibration laboratory where the sea going sensors are calibrated.

Temperature transfer standard calibration

As with most calibration laboratories, precision temperature measurements at IOSDL are carried out using well established bridge techniques involving the inductively coupled alternating current (ac) divider principle. The transfer standards presently in use at IOSDL to calibrate the sea going instruments include an Automatic Systems Laboratories (ASL) manually balanced F17 ac bridge system, using a platinum resistance thermometer (prt) and an external reference resistor, and a Neil Brown self balancing transfer standard, model CT-2. The resolution of the F17 bridge is equivalent to 0.00025°C and although the quoted accuracy is better than 0.0010°C we feel that a claim of 0.0004°C is more exact, based on experience and long term performance measurements. The CT-2 temperature transfer standard has the advantage of an engineering unit display with a resolution of 0.0001°C. The performance of the bridges as temperature measuring devices are not only dependant on the integral stability of the unit itself, but also on the quality of the prt and reference resistors used. The platinum resistance thermometer (prt) associated with the CT-2 instrument is a 25 Ohm device, model number 162D, manufactured by Rosemount Engineering and the reference resistor a Vishay 25 Ohm oven controlled component. Both the prt and reference resistor used with the F17 bridge are manufactured by H. Tinsley, (UK), the prt a quartz sheathed 5187SA model, and the 25 Ohm standard resistance a type 5685A based on a design originated by

Table 1. Transfer Standard Calibration
PRT Probe ASL708 Serial Number: 238708
Standard Resistance Serial Number: 239022

Cell Type	Standard Temp. °C	Bridge Ratio	Rstd Temp. °C	Standard Res. Ohms	PRT Res. Ohms
Mercury	-38.8331	0.850 257	20.5	24.999 940	21.256 379 8
Water	0.0099	1.007 163	19.5	24.999 868	25.178 942 1
Phenoxybenzene	26.8624	1.114 546	20.0	24.999 905	27.863 548 6
Gallium	29.7644	1.126 098 5	20.2	24.999 919	28.152 371 3
Ethylene Carbonate	36.3134	1.152 134	19.8	24.999 890	28.803 223 3

Table 2. Temperature sensor calibration data for second order polynomial fit (Equ. 6)

prt res. (x) Ohms	Std. Temp. °C	Y (calc.) °C	Std. Temp. - Y (calc.) °C
21.256379	-38.8331	-38.8331	-0.0000
25.178942	0.0099	0.0098	+0.0001
27.863548	26.8624	26.8626	-0.0002
28.152371	29.7644	29.7645	-0.0001
28.803223	36.3134	36.3132	+0.0002

Table 3. Pressure sensor calibration data for second order polynomial fit (Equ. 7).

CTD data (x)	Abs. Press. dbars	Y(calc.) dbars	Abs. Press - Y(calc.) dbars
-6.92	10.84	10.76	+0.08
98.31	109.96	109.82	+0.13
522.82	509.38	509.55	-0.17
1054.29	1009.84	1010.14	-0.30
1584.83	1510.06	1510.02	+0.04
2115.3	2010.21	2010.01	+0.20
2645.95	2510.40	2510.34	+0.07
3176.29	3010.70	3010.54	+0.16
3706.76	3510.91	3511.03	-0.12
4236.47	4010.89	4010.96	-0.09
4766.43	4511.28	4511.33	-0.05
5295.76	5011.22	5011.25	-0.03
5825.09	5511.41	5511.34	+0.07

F.J. Wilkins at the National Physical Laboratory (NPL). The reference resistors are returned to NPL on a regular basis, approximately every 18 months, to maintain calibration integrity and to build up a history of the long term stability. Both prts satisfy the ITS 90 specification for use as precision thermometers by satisfying one of the following relationships:

$$W(29.7646°C) > 1.118\,07$$
$$W(-38.8344°C) < 0.844\,235$$

where W(t90) = R(t90) / R(0.01°C)

Because the WOCE requirement is to measure temperatures below 0°C, be it only to -2°C, ITS90 stipulate that the prt must be calibrated over the range covered by the triple point of mercury (-38.8344°C), water (0.01°C), and the melting point of gallium (29.7646°C). In addition to these primary standards we also use two secondary standard tpcs (triple point cells), phenoxybenzene (26.8625°C) and ethylene carbonate (36.3135°C), to provide further calibration reference points. The preparatory work, prior to taking any measurements, start several days before when the room temperature controller is set to 20°C and the tpc maintenance baths are switched on. A day before, the water, phenoxybenzene and ethylene carbonate tpcs are prepared and allowed to reach equilibrium in their respective baths, and the prts and reference resistors are connected to the bridges and the power applied.

The calibration procedure itself is fairly labour intensive, taking several days to complete for one prt. For each prt, ten discrete bridge balance ratio readings are recorded at each standard temperature. A typical single set of the ratio measurements, for each reference temperature, is shown in Table 1, together with the standard resistance temperature recorded at the time of bridge balance. Note that the reference temperatures in Table 1 include a hydrostatic head correction commensurate with a prt immersion depth of 180 mm.

Using the standard resistance temperature information in Table 1, the temperature correction is applied to the reference resistance and the absolute value of the prt resistance is then evaluated from:

$$\text{Ratio} = R\,(prt) / R\,(std) \qquad [1]$$

Using the ITS90 'deviation functions' equations 2 and 3, which cover the mercury tpc to gallium melting point range, the constants 'a' and 'b' are first derived.

Hg to H_2O:

$$W1 - Wref- = a(W1-1) + b(W1-1)^2 \qquad [2]$$

H_2O to Ga:

$$W2 - Wref+ = a(W2-1) + b(W2-1)^2 \qquad [3]$$

Where:
'a' and 'b' are constants.
And the ratios:

W1 = prt res. at Hg tpc / prt resistance at H_2O tpc
W2 = prt res. at Ga mp / prt resistance at H_2O tpc

Wref- and Wref+ are the idealised prt defining ratios, Wr(t90) of the ITS90, for mercury (Hg) triple point and the gallium (Ga) melting point temperatures respectively. From ITS90:

Hg Wref- = 0.844 142 11
Ga Wref+ = 1.118 138 89

Values for W(t90) at other intermediate temperatures can then be derived by using the measured values for W(t90) and substituting in equation 4.

$$W(t90) - Wr(t90) = a(W(t90) - 1) + b(W(t90) - 1)^2 \qquad [4]$$

Over the oceanographic temperature range we do not use the full reference function advocated by ITS90, but instead use a restricted second order equation, equation 5, which provides a result to within 0.0001°C of that provided by the full function. This has the attraction of relative simplicity and ease of application.

$$t90 = 0.010\ 07 + 250.716\ (Wr(t90)\ -1) + 9.697\ 55\ (Wr(t90)\ -1)^2 \quad [5]$$

Alternatively we have found that by using a "best fit" polynomial equation, which relates the standard temperatures to the derived values of prt resistance, an equally accurate derivation of intermediate temperatures can be obtained. Table 2 is an example of a quadratic equation (equ. 6) derived from the calibration information shown in Table 1. The calculated values of temperature are shown and the differences from the standard temperatures are included.

$$Y\ (calc.) = C\ (x^2) + B\ (x) + A \quad [6]$$

Where:

Term		Coefficient
A	=	-2.4121690E2
B	=	9.1991545E0
C	=	1.5145164E-2

We also apply this technique to correct the display of the CT-2, by deriving a second order polynomial equation which relates the displayed temperature value with the standard temperature. Rather than disturb the electronic circuitry to correct the display on the CT-2, the corrected temperature is then displayed on a desk top computer.

Sea going sensor calibration

It is normal practise at IOSDL to carry out pre-cruise and post-cruise calibrations on all the sensors. This has the advantage of providing long term stability history and highlights any equipment problems. Procedures for calibrating the operational equipment are similar to the calibration of the transfer standards, with the laboratory temperature controlled at a nominal 20°C and the equipment prepared at least 24 hours before the start of recording the calibration data. For a temperature calibration this preparation work involves immersing the CTD sensors in a temperature controlled water bath, usually by using a hoist and suspending the equipment from overhead beams. The 100 litre temperature controlled bath has an integral heater and chiller unit and a temperature stability over several hours of better than 0.0005°C. It is usual to use both F17 and the CT-2 prts for a calibration as this provides a degree of redundancy plus an opportunity for cross correlation of the prt data. Both are placed in close proximity to the sensor probe, not more than 5 mm away, with the minimum obstruction of the water flow on the CTD sensor. Power is applied to the equipment, the bath temperature set to the lowest temperature of the calibration range required and the system allowed to stabilise over the next 24 hours.

Over the range 0°C to 25°C, at least ten sets of readings are recorded, with a greater concentration of measurements taken at the lower temperatures where the higher accuracy is required. At each step, ten samples are taken to provide sufficient data to calculate the mean and standard deviation. Best fit polynomial equations are then derived to relate the CTD data to each of the transfer standards and also to relate the transfer standards themselves. This latter calculation will provide information on any drift or fault condition with the prts. The calibration results are then inspected for errors and if these total, for confidence limits of not less than 95%, to within the accepted value of less than 0.002°C at near 0°C, the calibration is accepted. If not, the source of error is investigated and the calibration procedure repeated.

Errors and uncertainties occur throughout the calibration process, and it is important that they are identified and the magnitude assessed as far as possible. NPL quoted uncertainties of the primary fixed temperature standards gallium and mercury to be +0.0005°C, and for the water tpc 0.0001°C. Systematic errors of the bridges are near 0.0004°C; hydrostatic head corrections, self heating effects with the prts and temperature derived errors within the reference resistor (Gwilliam and Keene, 1993) all contribute to the overall deterioration of the required calibration accuracy.

Pressure calibration

As previously mentioned, a pressure calibration accuracy of 3 dbar over the full ocean depth range is the specified WOCE requirement for the CTD pressure sensors. This is approximately equivalent to 0.05% of 6000 metres, or 3 metres water depth. The pressure sensors in general use with the CTD are diaphragm type devices, with a strain sensitive full resistive bridge either bonded or unbonded to the dry side. Problems that are encountered with these devices include unwanted temperature sensitivities, causing both transient and steady state errors, the former could be tens of meters if the rate of change in temperature is high, and hysteresis effects can be 0.25% of full range output. The quartz based pressure sensors which are now coming into more general use are a large improvement on the strain gauge devices, with all the problems associated with the latter units greatly reduced.

The pressure calibration of sensors at IOSDL is carried out in the sea-going sensor calibration laboratory using a Budenburg dead weight tester (dwt), and a Paroscientific quartz pressure transfer standard model 740. It is intended that both of these instruments are returned for recalibration to a NAMAS (National Measurement Accreditation Service) accredited calibration laboratory at 18 month intervals. Present certificated pressure differences between the dwt and the NAMAS pressure vary from 0.03% of reading at pressures below 60 bar to 0.016% of reading at pressures up to 600 bar. For the 740 instrument, the pressure differences do not exceed 0.005% of full scale throughout the range, and the hysteresis amounts to + 0.01% of the full scale.

When carrying out a high accuracy pressure calibration, the quartz gauge is placed in the high pressure line from the dwt to the instrument to be calibrated. Although the dwt is not as accurate as the quartz device, it has the advantage of generating fixed stable pressure steps over the full pressure range. These steps can be held for a sufficient length of time to enable the quartz unit to make an absolute pressure measurement. This also has the attraction that the errors associated with a dwt can be ignored if the environment remains reasonably stable. The Paroscientific instrument has an integral display of pressure but can also be coupled to a computer via the RS232 link where the software can control the displayed engineering units and the sampling rate. The calibration procedure is relatively straightforward; the generated pressure from the dwt is connected to the input port of the sensor and the unit calibrated over the full range with measurements taken at ten equal pressure steps, taking care to allow the pressure to stabilise at each step. The procedure is then repeated with a decrease in pressure. A record is made of room temperature and the barometric pressure over the calibration period. To substantiate this calibration, the procedure is again repeated for an increase and decrease in pressure. The CTD, or sensor, being calibrated is then immersed into the temperature controlled water bath held at approximately 5°C, the system is allowed to stabilise and the calibration then repeated. The information provided by the calibrations at the two temperatures providing a figure for the steady state temperature coefficient. After a time period for the temperature to stabilise, the calibration is again repeated. The calibration data are corrected for any systematic errors, such as oil level difference between the measured pressure point and the sensor, and barometric pressure. The data are then fitted to determine the best polynomial equation (equ. 7). An example of a second order fit to a set of CTD pressure sensor calibration data is shown in Table 3.

To make a test on the behaviour of the sensor with a step change in temperature, the pressure source is removed from the sensor and allowed to stabilise at room temperature. The pressure output signal is then monitored at its maximum sample rate of 16 samples a second and the unit is then immersed into the temperature controlled bath of water held at 5°C. The unit is kept at this condition until the readings are stable, which could be in the region of 30 minutes. Using this data, scientists at sea can correct for this dynamic temperature effect in the near surface waters where temperature gradients are normally high.

$$Y\ (\text{calc.}) = C\,(x^2) + B\,(x) + A \qquad [7]$$

Where:

Term		Coefficient
A	=	1.727 212 4E1
B	=	9.414 240 3E-1
C	=	3.002 795 2E-7

Conclusion

The unpublished report from a SCOR-WG77 (Scientific Committee on Oceanic Research Working Group 77) CTD intercomparison experiment carried out at Kiel University in 1988 provided an estimate of the accuracy of the IOSDL pressure sensor to be 3 dbar and the temperature to be 0.002°C near 0°C and 0.004°C near 30°C. Both pressure and temperature calibration facilities at IOSDL have been considerably enhanced since that experiment, and this effort will be reflected in improved standards.

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Modifications to the EG&G Non-data Interrupt Multisampler Pylon Units

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During a series of three WOCE cruises on RRS Discovery from December 1992 to May 1993 problems were experienced with the operation of the IOSDL 24 bottle GO Rosette Multisampler (Model 1015) units. The Laboratory's Neil Brown Mk IIIb CTD/Multisampler system had been updated with the EG&G Non-data interrupt deck and pylon units, *i.e.* the former GO electronic components in the underwater unit had been replaced by EG&G electronics.

A number of problems recurred despite frequent attention and servicing of the equipment. Extreme care was taken when setting the length of the Niskin bottle lanyards. If the tensions were too low the bottles would trip prematurely, if they were too tight the multisampler stepper motor would misfire. It was also possible for sea water to leak into the motor housing past the drive shaft seal and settle on the 24 way confirmation switch. This led to misfires being indicated when a bottle had fired. Frequent misfires continued to occur even after repeated servicing and only after careful analysis of all the sample data could one be fairly certain of where bottles had fired.

The motor housing is situated in an oil filled pressure-balanced pylon. The motor housing is 0.010" longer than the recess in the pylon in which it sits, allowing the pressure of the pylon top plate to hold it in position.

GO unit (notional)	VPeak	56.0V	IPeak	3.5 A	PPeak	196.0W
GO unit (actual)	VPeak	51.2V	IPeak	3.2 A	PPeak	163.8W

Stepper motor DC resistance - 16 ohms
Pulse width 11 milliseconds (approximately)

On one of our units the motor housing was shorter than the pylon recess, thus the top plate did not come into contact with it and therefore could not hold it in position. This allowed the motor housing to rotate in reaction to the firing operation. This meant that the housing had to be frequently repositioned, not an easy task to get right without jigs or information on how this should be carried out correctly.

After the cruises we sought ways to improve the firing reliability of the EG&G Non-data interrupt underwater units.

In simple terms, for the GO system when the trigger button is pushed, both CTD and CTD deck unit are disconnected from the sea cable. A DC power supply then charges a large capacitor in the underwater unit. After approximately 15 seconds the charge voltage reaches 56 VDC. An electronic switch then discharges the capacitor through the stepper motor firing a bottle. A confirmation signal is sent to the Multisampler deck unit on correct rotation of the drive shaft. The CTD and deck unit are then reconnected to the sea cable for normal operation.

If an EG&G deck unit and pylon are used, power is supplied continuously to both the CTD and Rosette underwater units. A series of 1.6 KHZ tones is sent to and from the underwater unit to control the fire and response sequences. A transformer couples these tones and electrically isolates the Rosette electronics from the CTD. The stepper motor is actuated in a similar way to the GO units but with the capacitor charge voltage limited to 47 VDC. The Rosette underwater unit is not disconnected from the sea cable during a fire sequence.

The capacitors are only of 50 VDC working value and small physical size, thus limiting the charge voltage. If we look at the peak power available to drive the stepper motor, the EG&G versions fall short of the GO units, possibly adding to the firing unreliability of the Rosette units.

To improve this situation, IOSDL have modified their EG&G units. The capacitor bank and PC board mounted at one end of the electronics unit was replaced by another using components of the same value but of higher working voltage (63 VDC). The 47V limiting Zener diode was replaced with a 56V version.

Three EG&G units were modified and the improvements in power shown in Table 1.

Tests were carried out with both original and modified EG&G units over a range of supply voltages. Each unit was triggered 5 times at 30 second intervals and the average firing voltage tabulated against supply voltage.

Both GO and EG&G units were tested using a simulated sea cable but without a CTD connected. Voltages quoted below are peak values measured across the stepper motor, and are for one multisampler unit only. There may be variations between individual units, but spot measurements on two others show these to be small.

Table 1. Performance of original and modified EG&G Non-data interrupt deck unit in conjunction with an unloaded 24 bottle GO Pylon with one set of EG&G electronics

Supply Voltage (volts)	**Peak Firing Voltage (volts)**		**Peak Current (Amps)**		**Peak Power (Watts)**		**Power Difference (Percent)**
	Original	Modified	Original	Modified	Original	Modified	
22	45.84	45.4	2.84	2.04	131.3	128.8	-1.9
23	47.44	48.16	2.97	3.01	140.7	145.0	3.1
24	48.0	50.24	3.00	3.14	144.0	157.8	9.6
25	48.0	52.16	3.00	3.26	144.0	170.0	18.1
26	48.4	54.8	3.03	3.43	146.4	187.7	28.2
27	-	55.2	-	3.45	-	190.4	30.1
28	48.4	55.6	3.03	3.48	146.4	193.2	32.0
29	-	56.0	-	3.5	-	196.0	
30	48.8	56.0	3.05	3.5	148.8	196.0	31.8
32	-	56.0	-	3.5	-	196.0	

Pulse width - 20 milliseconds.

There is a small modification necessary in addition to the changes made to the Rosette unit. When a Neil Brown/ EG&G system is used with the EG&G Rosette unit, the supply voltage to the Rosette underwater unit is limited to 24 VDC by a Zener diode in the CTD circuit. A resistor needs to be connected in series with the CTD supply line from the Rosette underwater unit. This can be mounted in either the CTD or the Rosette. (In the IOSDL case a separate pressure housing is used as a junction box to connect various parts of the system together. This extra resistor is included here.) The value of the resistor depends upon the current drawn by individual CTD systems and should be chosen to allow a 30 VDC supply across the Rosette unit. Some of the earlier IOSDL CTD units had a 22V Zener diode thus further limiting the supply. These have in fact been updated but this is incidental due to the requirement for a series resistor.

There are two versions of Rosette unit manufactured, namely the non-intelligent and the intelligent types. IOSDL have the non-intelligent type. Further work to be carried out is to investigate the possibility of adding a positive indication of the bottle closure not just an indication that the stepper motor has or has tried to rotate (this is what is missing).

From the table of results, the modified EG&G unit is best operated in the range 27-32 VDC since the improvement in available power exceeds 30% compared with the values for the units before modification.

Details of the Rosette modifications are available from J. Smithers, IOSDL.

MEETINGS TIMETABLE 1994

March 14-19	Joint Scientific Committee (JSC-XV), Geneva, Switzerland.
March 31-April 1	Atlantic Float Meeting, AMS, Boston, MA.
April 12-15	JSC Ocean Observing System Development Panel (OOSDP-IX), BMRC, Melbourne, Australia.
April 18-21	Intergovernmental Global Ocean Observing System (IGOOS), Melbourne, Australia.
April 20-22	WOCE Core Project 3 Working Group (CP3-7), Fuengirola, Spain.
April 25-29	European Geophysical Society XIX Assembly, Grenoble, France.
April 25-27	TOGA/WOCE XBT/XCTD Programme Planning Committee (TWXXPPC-3), Miami.
April 28-29	WOCE Upper Ocean Thermal Data Assembly Centres Coordination Group (UOT/DAC-V), Miami, FL.
May 9-13	US Atlantic Meeting, GFDL, Princeton, NJ.
May 19-20 (or 24-25)	WOCE Hydrographic Programme Data Meeting, Washington, DC.
June(?)	WOCE Data Management Committee Integrated Data Set Workshop, Tallahassee(?)
July 19-22	The Oceanography Society Pacific Basin Meeting, plus WOCE Core Project 1/Core Project 2 (Informal Meeting), Hilton Hawaiian Village, Honolulu, HI.
August 15-19	"The South Atlantic: Present and Past Circulation" Symposium (plus Deep Basin Experiment Meeting), Bremen, Germany.
August	WOCE SSG EXEC-9(?), USA (?)
September 19-21	WOCE Numerical Experimentation Group (NEG-9), Los Alamos, NM.
October 3-7	JSC Ocean Observing System Development Panel (OOSDP-X), Dallas, TX.
October 10-11	Warm Water Sphere, Kiel, Germany.
October 12-14	WOCE Scientific Steering Group (WOCE-21), Kiel, Germany.
October 18-19	Intergovernmental WOCE Panel (IWP-3), Paris, France.
November 2-4	WOCE Hydrographic Programme Planning Committee (WHP-13), Kaohsiung, ROC.
December	WOCE Data Management Committee (DMC-7).

WOCE is a component of the World Climate Research Programme (WCRP), which was established by WMO and ICSU, and is carried out in association with IOC and SCOR. The scientific planning and development of WOCE is under the guidance of the JSC Scientific Steering Group for WOCE, assisted by the WOCE International Project Office. JSC is the main body of WMO-ICSU- IOC, formulating overall WCRP scientific concepts.

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Scientific material should not be used without agreement of the author.

We hope that colleagues will see this Newsletter as a means of reporting work in progress related to the Goals of WOCE as described in the Scientific Plan. The SSG will use it also to report progress of working groups, experiment design and models.

The editor will be pleased to send copies of the Newsletter to institutes and research scientists with an interest in WOCE or related research.